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Pitch First, Stress Next?
Prosodic Effects on Word Learning in an Intonation Language

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1. Introduction

The acquisition of phonology requires learning to interpret phonetic variation. Across languages, prosodic properties may vary both in their acoustic correlates and the phonological domains they signal. The correlates of stress are known to vary cross-linguistically, with languages using various combinations of suprasegmental cues (duration, pitch and intensity) and sometimes also segmental cues (differences in vowel quality). The co-variation between stress and pitch accent also patterns differently across languages, with some languages showing pitch accents in nearly every lexical word and others showing a more sparse accentuation (Hellmuth 2007). Importantly, variation in stress and pitch may be relevant to meaning at different levels of phonological structure: stress signals lexical contrasts in free stress languages like Spanish or English but not in a fixed stress language like French, where it is a phrasal property (Peperkamp, Vendelin & Dupoux 2010); pitch signals word contrasts in Chinese or Japanese but not in English, where it only conveys phrasal meanings (Gussenhoven 2004). Therefore, the task for the young learner is to determine which variation is meaningful and at what prosodic level (lexical or phrasal).

Discrimination studies have shown early sensitivity to pitch as a general ability, but not early sensitivity to stress. Infants from both intonation (French, English) and tonal (Chinese) languages show early discrimination of tonal contrasts regardless of their language-specific relevance (Nazzi, Floccia & Bertoncini 1998; Mattock & Burnham 2006; Mattock, Molnar, Polka & Burnham 2008). Sensitivity to stress contrasts seems to evolve later and is dependent on the native language, especially if more varied stimuli are used:

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between 6 and 9 months, English, German and Spanish infants show a developmental change in discrimination abilities not present in French infants (Skoruppa, Pons, Christophe, Bosch, Dupoux, Sebastián-Gallés, Limissuri & Peperkamp 2009; Höhle, Bijeljac-Babic, Herold & Weissenborn 2009, Skoruppa, Pons, Peperkamp & Bosch 2011). However, both language specific lexical tone perception and stress perception seem to be in place by 9 months.

Together with changes in perceptual sensitivity, by the end of the first year of life infants start to encode differently phonetic variations that impact on word meaning from those that don't. Word recognition studies have shown that after 9 months infants are able to disregard variation related to speaker identity, emotion, or pitch register (Werker & Yeung 2005; Singh, White & Morgan 2008); at 11 months, changes in stress patterns do not block word recognition, although infants' responses are delayed (Vihman, Nakai, DePaolis & Hallé 2004); and around 14 months words are recognized in incorrect stress and/or intonation conditions, although there is sensitivity to both factors (Fikkert & Chen 2011). For one-year-olds, the ability to learn novel word-object links seems to depend on the salience of the phonetic contrast, and success in the discrimination of that contrast or in word recognition tasks does not predict success in learning novel word-object pairings. Infants' ability to interpret phonetic variation in words seems to undergo a fundamental change before 20 months of age, with increased access to relevant phonetic detail (Werker & Yeung 2005). Recent research on word learning targeting stress and pitch contrasts has shown that 14-month-old English infants are able to use lexical stress, and English-speaking two-year-olds discard pitch contours as lexically relevant (Curtin 2009; Quam & Swingley 2010). This early use of the stress contrast suggests that it is salient enough in English. However, the issue whether salient intonational contrasts in English would be treated alike at early stages has not been investigated to our knowledge, neither has the use of stress or pitch contrasts in novel word-object associations in other intonation languages with free stress.

European Portuguese (hereafter EP) is an intonation language with free lexical stress. Stress is thus a word-level property and its position is confined to one of the word's last three syllables. Morphology plays a role in stress location, whereas there is no sensitivity to weight (Mateus & Andrade 2000). Stress cues in EP are similar to English in the presence of vowel reduction together with the use of suprasegmental cues. In the absence of vowel reduction, duration is the main cue to word stress (Andrade & Viana 1989; Delgado Martins 2002). Stress can be lexically contrastive, as shown by word pairs like *bambo* ['bẽbu] 'unsteady' / *bamboo* [bẽ'bu] 'bamboo', or *crítica* ['kritikẽ] 'criticism' / *critica* [kri'tikẽ] 'criticize'. Unlike stress, pitch is a property of phrase-level phonology. Pitch contrasts signal phrase level meanings, such as pragmatic or discursive meanings, and sentence types (Frota 2002, in press). Unlike English or Spanish, EP shows a sparse pitch accent distribution, and thus low co-variation between stress and pitch accent (Vigário & Frota 2003).

There are no prior perception studies on the acquisition and development of stress and pitch contrasts in EP. Early production studies have shown that stress patterns tend not to be correctly produced from the start: early words show level stress, a tendency to the weak-strong pattern, and also stress shift (Frota & Vigário 2008; Frota & Matos 2009; Correia 2010; Matos 2010). Unlike lexical stress, meaningful pitch contrasts have been shown to be produced quite early in development (around 1;5 – Frota & Vigário 2008; Vigário, Frota & Matos 2011).

The present study examines the role of contrastive stress patterns and contrastive pitch contours in novel word-object pairings in European Portuguese. Using an eyegaze-based procedure, we tested one to four-year old EP learners' interpretation of stress and pitch variations when learning sound-object associative links. Two main questions are addressed: (i) Will young learners notice stress differences and/or intonation differences in 'new words' ?; (ii) When do young learners interpret phonetic variation at the appropriate levels according to their native language ?

2. Method

2.1. Participants

Ninety-three children between 1;0 and 4;09 were tested in Lisbon, all from monolingual EP homes. Forty-nine children have successfully performed the task, that is they learned the word-object associative link. The criteria for success in the task was looking time above chance (> 50%) to the object picture associated to the novel word in the training. Two children were excluded due to experimenter error. Parents filled in a preliminary EP version of the CDI form. Mean age and CDI mean scores for the participants are provided in Table 1.

Table 1. Information on the participants on the experiment by age.

	Participants	Mean age (months)	Children included	Mean age (months)	CDI mean score (%)
1-year old	26	16.92	11	16.27	19.64
2-year old	25	30.54	11	29.90	65.16
3-year old	25	42.43	14	43.46	84.77
4-year old	17	53.53	13	52.93	89.13

The results reported below are from the 49 children that successfully participated in the study.

2.2. Materials

Four tokens of the disyllabic word form [milu] were recorded by a female native speaker of EP in child directed speech. Two of them were produced with a declarative intonation but contrasting stress patterns: ['milu] vs [mi'lu]. The other two show the same penult / final stress contrast but were uttered with a question

intonation. All of them were pseudowords in EP. The four tokens were preceded by the article *o* ‘the’ or were the nuclear word in the short utterances *Olha para o TOKEN* ‘Look at TOKEN’, *Este é o TOKEN* ‘This is TOKEN’, *Está aqui o TOKEN* ‘Here is TOKEN’.

A disyllabic word form was chosen because this is the most frequent word shape in EP, both in adult speech and child directed speech (above 40% - Vigário, Freitas & Frota 2006; Frota, Vigário, Martins & Cruz 2010). High vowels were used to avoid vowel reduction and ensure that the stress contrast was instantiated by suprasegmental cues only. Penult stress and final stress are the two most frequent stress patterns in EP (monosyllables excluded, the figures are 76% and 22% in adult speech, and 67% and 32% in child-directed speech – Frota et al. 2010). Stress location was cued by relative syllable duration (with stressed syllables 58 to 132 ms longer than unstressed syllables) and by the alignment of the pitch fall, as pitch always falls through the stressed syllable (Figure 1). Declarative and question intonation are distinguished by their different nuclear contours: H+L* L% in declaratives; H+L* LH% in questions (Frota 2002). Thus the declarative / interrogative intonation contrast is cued by the low vs rising boundary, as shown in Figure 1. This contrast is also cued by the duration of the final syllable, which is 117 to 165 ms longer in interrogatives.

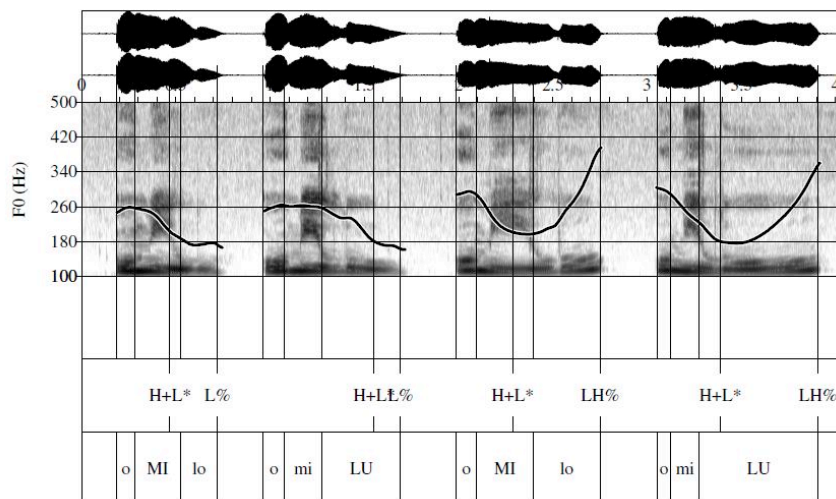


Figure 1. The four stimuli *o [milu]* ‘the [milu]’: penult stress declarative, final stress declarative, penult stress interrogative, and final stress interrogative.

Each novel word was associated with one of the two visual stimuli in Figure 2. For each participant, one of the two toys was labeled [milu] with a given stress pattern and intonation, whereas the other toy was never labeled.



Figure 2. The two toys used in the experiment.

2.3. Apparatus and procedure

The experiment was conducted in a dimly lit and sound attenuated laboratory room. Children sat on the parent's lap in front of the screen of an SMI eye-tracker (RED), on which they viewed pictures. Concealed speakers played the recorded utterances that referred to the pictures.

We used an eyegaze-based procedure (similar to Quam & Swingley 2010) where visual fixation to the picture labeled in the learning phase is the response variable. The experiment lasted nearly two minutes and consisted of three phases: animation, ostensive-labeling and test. The first two make up the learning phase, where the novel word-object pairing (the trained word) is taught. In the animation phase, a doll introduced two toys, but only one of them was labeled. The other was present equally often but was not labeled. In the ostensive labeling phase, the labeled toy from the animation was repeatedly labeled. This learning phase lasted 46 seconds during which the participant listened to the trained word associated with one of the toys (with dolphin and turtle counterbalanced across participants). Finally, in the test phase pictures of the two toys appear side by side while children listened to the trained word and to stress / pitch deviant versions of it. The order of picture presentation (left / right) was counterbalanced across trials. The child's eye movements were automatically recorded by the eye-tracker (Figure 3).

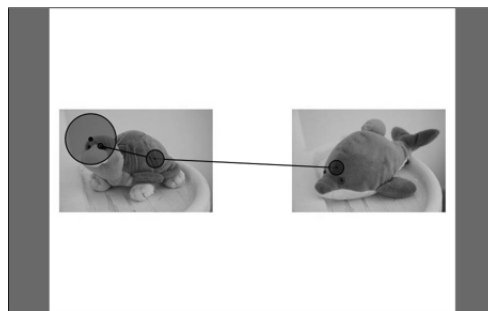


Figure 3. Image of the scan-path obtained in one of the trials.

The test phase contained 12 trials of 4 seconds each. Each trial was preceded by a blinking cross at the center of the screen with a duration of 1,5 seconds. The test trials included 4 trained trials and 8 change trials (6 stress or pitch change trials and 2 stress and pitch change trials). Eight trials were noun phrase trials (NP) and 4 were short utterance (UTT) trials. The target word started at about 360 ms (NP) and 670 ms (UTT) from trial onset.

The trained words were either penult stress declarative, final stress declarative, or penult stress interrogative, and children were randomly assigned to one of these training conditions. The deviant versions consisted of a stress change (SC), an intonation change (IC) or both changes together (BOTH). If children have learned the word-object link, they should look longer to the labeled object picture than to the unlabeled one when listening to the trained word. If they were sensitive to any of the prosodic changes, they should look less to the labeled object picture in the deviant pronunciations than in the trained word.

3. Results

The proportion of the looking time to the picture labeled in the learning phase (the time looking at the labeled object picture divided by the total looking time for both pictures) was calculated for each subject in each test trial. We used two time windows after the onset of the target word: 367+2000 ms for one and two-year-olds, and 367+1500 ms for three and four-year-olds (Fernald, Pinto, Swingley, Weinberg & McRoberts 1998; Swingley & Aslin 2002; Quam & Swingley 2010; Fikkert & Chen 2011; Gredebäck, Johnson & von Hofsten 2010).

The analysis of looking behavior before the target word was heard showed no bias towards any of the object pictures (mean = .47, $t(92) = -1.51$, $p = .13$). We determined whether children had learned the trained word by comparing children's fixation to the labeled picture to chance fixation. As mentioned above, only children with a fixation > 50% were included in the analysis (mean = .67, $t(48) = 8.92$, $p < .001$). Next we asked whether there was any difference between children's responses to the NP trials ('the milo') and the UTT trials ('Look at the milo'). No difference was found both for trained words ($t(48) = -1.46$, $p = .15$) and deviant pronunciations ($t(48) = -.91$, $p = .37$).

The main analysis examined whether children responded to the deviant pronunciations (SC, IC, both). An ANOVA on the proportion looking time to the labeled picture, with the within-subject factor 'condition' (trained, SC, IC, BOTH) and the between-subjects factors 'learning phase' (penult-decl, final-decl, penult-int), and 'age' (younger=one and two-year olds, older=three and four-year olds), revealed a significant main effect of condition ($F(3,126) = 9.7$, $p < .001$, $\eta^2 = .19$) and a significant interaction between condition and age ($F(3,126) = 2.98$, $p < .05$, $\eta^2 = .07$). Post-hoc analysis revealed significant differences between trained pronunciation and all the other conditions (trained

vs SC: mean difference = .135, $p < .001$; trained vs IC: mean difference = .070, $p < .05$; trained vs BOTH: mean difference = .202, $p < .001$) and between IC and BOTH conditions (mean difference = .131, $p < .01$). No other main effects or interactions were found.

Figure 4 shows mean proportion looking times to the labeled object picture per condition by younger and older age groups. Paired t -tests were carried out for each of the two age groups separately. The first set of t -tests compared children looking times in each condition to chance fixation (Table 2). The second set of t -tests compared children looking time across conditions (Table 3).

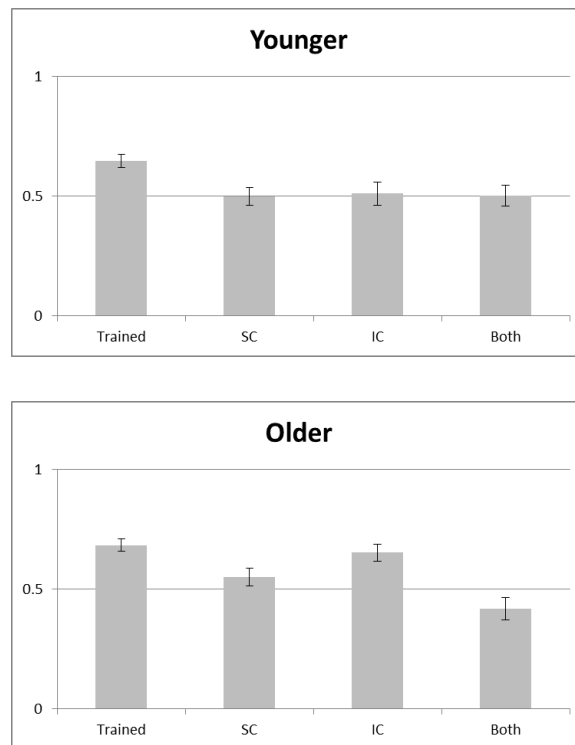


Figure 4. Proportion looking time to the labeled object picture across the four conditions, by age group: younger group (one and two-year olds) in the top panel; older group (three and four-year olds) in the bottom panel. Error bars represent +/- 1 Standard Error.

Table 2. Paired *t*-test results of looking time to the labeled picture against chance by condition, for each age group.

Age group	Trained	SC	IC	BOTH
Younger	$t(21) = 5.4,$ $p < .001$	$t(21) = -.02,$ $p = .98$	$t(21) = .21,$ $p = .84$	$t(21) = .08,$ $p = .94$
Older	$t(26) = 3.2,$ $p < .01$	$t(26) = 1.4,$ $p = .19$	$t(26) = 4.3,$ $p < .001$	$t(25) = -1.7,$ $p = .1$

Table 3. Paired *t*-test results of looking time to the labeled picture across conditions, for each age group.

Age group	Trained/SC	Trained/IC	Trained/BOTH	SC/IC
Younger	$t(21) = 3.3,$ $p < .01$	$t(21) = 2.4,$ $p < .05$	$t(21) = 3.2,$ $p < .01$	$t(21) = -.19,$ $p = .85$
Older	$t(26) = 7.2,$ $p < .001$	$t(26) = .82,$ $p = .42$	$t(25) = 4.7,$ $p < .001$	$t(26) = -2.2,$ $p < .05$

The results revealed that younger children's looking time was not significantly above chance in any of the deviant conditions, showing that they were sensitive to any of the prosodic changes tested. Further, the paired *t*-tests of each deviant condition against trained pronunciation showed that looking times to the labeled picture in the deviant conditions were significantly shorter than the looking time in the trained pronunciation condition. The results for the older children revealed a different pattern. Looking time to the labeled picture was significantly above chance in the IC condition. Only the SC and the BOTH conditions showed significantly shorter looking times than the trained condition. Unlike for the younger group, the looking times to the labeled picture in the SC and IC conditions were significantly different. These results indicate that older children were no longer sensitive to the intonation change.

Furthermore, in order to check for a possible trend in the data within each of the two age groups, we computed Pearson's correlation coefficient (one-tailed) between age (in months) and children's performance in each condition. There were no significant correlations with age within the younger group, with the exception of a positive correlation between age and the trained pronunciation condition, indicating that older children within the younger group were better in the task of learning the novel word-object pairing ($r = .41, p < .05$). There were no significant correlations between age and any of the conditions within the older group. For all the children data, the only significant correlation was between age and IC ($r = .37, p < .001$), reflecting the change in sensitivity to pitch as expected. We also measured the correlation between children's vocabulary size (based on the CDI mean scores) and their sensitivity to the prosodic changes. There was no evidence for any correlation, both within the younger (SC: $r = .16, p = .27$; IC: $r = .06, p = .42$; BOTH: $r = .29, p = .13$) and

older group (SC: $r = .09, p = .36$; IC: $r = -.35, p = .06$; BOTH: $r = -.26, p = .14$), or overall (SC: $r = .18, p = .15$; IC: $r = .23, p = .09$; BOTH: $r = -.12, p = .24$).¹

4. Discussion

In this study we examined the role of contrastive stress patterns and contrastive pitch contours in novel word-object pairings in European Portuguese, an intonation language with free lexical stress. The results obtained demonstrate that pitch contour variation was regarded as relevant by one and two-year olds, at odds with native language phonology. However, three-year olds were able to disregard pitch variation, suggesting a developmental change towards native language phonology around the end of the second year of life. Unlike pitch contour variation, stress variation was regarded as meaningful, both by the younger and older age groups. Overall, these results show that only at 3;0 do young learners interpret phonetic variation at the appropriate levels according to the native language.

Our findings add to the as yet small body of evidence on how prosody impacts on word meaning at early stages of development. Early sensitivity to stress variation in EP is in line with Curtin's (2009) findings for English. In both languages, one-year olds were able to detect stress changes in novel words. This suggests that the suprasegmental cues to stress are salient enough in both languages (and even in the absence of vowel reduction). However, early sensitivity to pitch variation in EP partially contradicts previous findings on other languages. In word recognition, changes in pitch register were discarded by English infants by 9 months (Singh et al. 2008); In word learning, English children disregarded changes in pitch contours by 2;5 (Quam & Swingley 2010). It is not known, however, whether English-learning children before 2;5 include pitch contours among the dimensions of variation relevant to lexical meaning. Fikkert & Chen (2011) have shown that correct intonation has an effect on word recognition in Dutch 24-month-olds. Thus, it is an open issue whether early sensitivity to intonation contrasts in tasks tapping words is a more general property (perhaps akin to early sensitivity to pitch in discrimination) or a language-specific feature.

Previous studies have established early discrimination of phonetic contrasts regardless of their language-specific relevance, as well as early sensitivity to non-phonological aspects of the phonetic form of words in word recognition (Werker & Tees 1984; Werker & Yeung 2005; Saffran, Werker & Werker 2006). In word learning, by contrast, access to some aspects of phonetic detail seems to be available by 18~20 months, as only salient phonetic contrasts tend to be used earlier (Werker & Yeung 2005; Swingley 2009; Curtin, Fennell & Escudero 2009). Our findings, together with Curtin's (2009), strongly suggest

¹ The result for IC in the older group showed a borderline almost significant negative correlation. As the CDI scores for the older group are quite high, we attribute this to a possible ceiling effect.

that prosodic contrasts are among the salient properties that are assessed in more demanding tasks earlier in development, regardless of their language-specific function. This role of prosodic properties adds to the special status of prosody in early language acquisition (Jusczyk 1997; Höhle 2009) by extending the early use of prosody to word learning. Recent studies showing that salient pitch variation increased phonetic recognition by infants (Lebedeva & Kuhl 2010) and that intonational breaks promoted both word segmentation and word-object associative links (Shukla, White & Aslin 2011) are in line with this view. In summary, the current findings suggest that prosodic properties play an important role in early word representations. In the case of European Portuguese, phonological development in early word representations seems to proceed from pitch and stress to stress only, by fine tuning to the dimensions (stress – lexical / pitch – phrasal) relevant in the native phonology.

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