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# Infants' perception of the intonation of broad and narrow focus

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Abstract

Infants perceive intonation contrasts early in development, in contrast with lexical stress but similarly to lexical pitch accent. Previous studies have mostly focused on pitch height/direction contrasts, however, languages use a variety of pitch features to signal meaning, including differences in pitch timing. In this study, we investigate infants' perception of the prosodic contrast that cues the difference between all-new information (broad focus) and the highlighting of a particular word (narrow/contrastive focus) in European Portuguese (EP), and which has been described as having pitch timing as its key feature. Using a modified version of the visual habituation paradigm, EP learning infants discriminated this contrast at 12 months, but not at 7 months, deviating from previous findings of a precocious ability to perceive pitch distinctions. These results suggest different developmental trajectories of the perception of different prosodic contrasts, underlining the importance of the nature of the cues signalling a given contrast in a given language.

(Word count - 154)

Introduction

Intonation can be defined as “the structured variation in pitch which is not determined by lexical distinctions” (Gussenhoven, 2007: 253). The principal dimensions on which pitch can vary are pitch height, pitch direction and pitch timing (the temporal coordination of pitch turning points, that is of changes in pitch height or direction, with the consonants and vowels). Pitch variation is often accompanied by changes in duration and intensity. In intonation, pitch varies independently of lexical items and is used to convey meanings at the phrasal or sentence levels. Sentence type distinctions and the highlighting of important information are among the phrasal meanings conveyed by intonation across languages. Although these functions of intonation are quite general, the prosodic cues used to express such meaning distinctions are language-specific (e.g., Ladd, 2008). Thus, an important part of the language acquisition process involves the perception of the prosodic cues that are relevant to meaning within the native language. This paper investigates the development of infants’ perception of intonation by examining a prosodic contrast that is used to highlight important information in European Portuguese (EP). In EP, the difference between all new information, or broad focus, and the highlighting of a particular word, or narrow/contrastive focus, is conveyed by a set of prosodic features whose key element is a pitch timing contrast (Frota, 2000, 2014).

Little is known about the developmental course of infants’ perception of linguistic intonation. Prior research looking at pitch contrasts has mostly focused on the acquisition of lexical pitch, that is of pitch variations that are meaningful at the word level, such as lexical tone and lexical pitch accent distinctions. It has been shown that learners of tone languages, such as Mandarin or Cantonese, show stable discrimination of acoustically distinct lexical tones throughout the first year, as early as 4 months (Mattock & Burnham, 2006; Mattock, Molnar, Polka & Burnham, 2008; Yeung, Chen & Werker, 2013; but see Tsao, 2008, showing one-year-old Mandarin learning infants have difficulty discriminating acoustically similar tones). For lexical pitch accent, it is known that Japanese learning infants are able to discriminate native pitch accent contrasts from as early as 4 months, and this discrimination ability is maintained throughout the first year (Sato, Sogabe, & Mazuka, 2009). However, these early abilities to discriminate native lexical pitch contrasts differ for tone and lexical pitch accent in the presence of phonetically varied contexts. Early discrimination of lexical tone seems to be negatively affected by phonetic variability (Shi, 2010), whereas discrimination of lexical pitch accent is not affected (Sato et al. 2009).

Very few studies have investigated infants' discrimination abilities for intonation, and those which have, focused on perception relating to sentence type distinctions. Best, Levitt & McRoberts (1991) examined both native and non-native discrimination of exclamations and wh-questions by English learning infants, and found that 6-8 month-olds were able to discriminate both native and non-native (Spanish) contrasts, however 10-12 month-olds failed to discriminate either. These results appear to counter the view that discrimination abilities are refined through exposure to the native language. However, Best et al.'s (1991) stimuli contained both word order (inversion in wh-questions) and lexical properties (presence of wh-word), in addition to the prosodic cues, which could have impacted upon the performance of infants. Geffen & Mintz (2011) investigated discrimination of the statement/yes-no question contrast using stimuli that also included word order cues as well as intonation cues. They found that, at 7 months, English learning infants successfully discriminated the two sentence types. However, as in Best et al.'s study, it is not clear whether infants were attending to the intonation correlates of the sentence type distinction or the lexical/word order cues present in the stimuli.

Only two studies have investigated sentence type distinctions using stimuli that differ on prosodic cues only. Soderstrom, Ko and Nevzorova (2011) used multiword, uninverted yes-no question and statement sentences, thus neutralizing the word order cue to questions in English. They found an overall preference for questions but no direct evidence of discrimination. This could indicate a general preference for high/rising pitch (e.g., Trehub, Bull & Thorpe, 1984; Papoušek, Bornstein, Nuzzo, Papoušek & Symmes, 1990). However, due to the broad range of ages used in the study (4.5 to 24 months), it is difficult to conclude about the developmental trajectory of perceptual abilities from their data. In addition, the intonation used within each sentence type in their stimuli was very variable (e.g., declarative sentences ending with either flat, falling or bell shaped contours), which may have affected infants' perception of the contours. Frota, Butler & Vigário (2014) utilised single prosodic word utterances differing in prosodic cues related to the statement/yes-no question contrast in European Portuguese, a language that marks this contrast by prosodic cues only (in EP, unlike in English, there is no inversion in yes-no questions – Mateus, Brito, Duarte, Faria, Frota, Matos, Oliveira, Vigário, & Villalva, 2003). They found that both 5-6 and 8-9 month-old European Portuguese learning infants were able to discriminate the sentence type prosodic contrast despite segmental variability. In contrast with Soderstrom et al.'s study, the intonation contours in Frota et al.'s study showed a falling pattern for the declarative and a falling-rising pattern for the interrogative, with low variability within sentence type evident in the stimuli. Similarly to Soderstrom et al., question stimuli showed longer durations than statements. To our knowledge, Frota et al. was the first study to demonstrate successful infant discrimination of an intonation contrast, suggesting precocious discrimination abilities for intonation similar to those reported for lexical pitch accent.

The precocious discrimination abilities for lexical pitch accent and intonation are in line with infants' sensitivity to, and ability to utilise, pitch from a very early age. For example, infants have been shown to be able to use pitch as a cue to segment clauses (although pitch was insufficient on its own, but rather was used in conjunction with either pause or preboundary lengthening, Seidl, 2007). Also at 6 months, infants can utilise pitch reset (together with preboundary lengthening) as a cue to prosodic phrase boundaries in order to guide word segmentation (Shukla, White & Aslin, 2011). Although infants do not necessarily use pitch cues in an adult-like fashion, they are sensitive to and able to linguistically use pitch cues very early in development.

English-learning Infants' sensitivity to pitch seems to develop throughout the first few years. During early word segmentation development, infants have been shown to perceive pitch variation as relevant for word recognition at 7.5 months, and it is only at 9 months that pitch and amplitude changes are both disregarded as relevant for word recognition (Singh, White & Morgan, 2008). Later in development, 4-5 year olds have learnt to use pitch cues as a guide to emotion, whereas other cues such as facial and body language cues are the ones utilized earlier, at 2-3 years (Quam & Swingley, 2012).

Previous studies that have examined infants' perception of specific features of linguistic pitch, both at the lexical and phrasal levels, have focused on pitch height and pitch direction contrasts. For example, the lexical tones examined in Yeung, Chen & Werker (2013) were the high rising tone and the mid level tone (i.e., the Cantonese Tones 25 and 33). The Japanese lexical pitch accent contrast studied in Sato et al. (2009) consisted of High-Low versus Low-High words. The sentence type distinction investigated by Frota et al. (2014) was cued by low pitch in statements versus rising pitch in questions (i.e., L% and LH%). In Seidl (2007) and Shukla et al. (2011) studies on clause and word segmentation, differences in pitch level and/or pitch shape may also have been the cues that were used. By and large, these studies have shown an early sensitivity to pitch contrasts in the first year of life, as described above. However, languages may use a variety of pitch features to signal similar lexical or phrasal meanings. These include differences in pitch height, pitch direction, pitch register and pitch timing (i.e. the temporal location of pitch turning points in the syllable). For example, in tone languages, tones can be distinguished by pitch height and pitch direction (e.g., in Thai and Mandarin, Mattock & Burnham, 2006; Duanmu, 2007), as well as the temporal location of the pitch turning point (e.g., in Mandarin, Shen & Lin, 1991). Similar distinctions can be found in languages with lexical pitch accent: for example, while Serbo-Croatian has both falling and rising word accents (Godjevac, 2005), Swedish uses a pitch timing contrast to distinguish two word accents (early versus late timing of the pitch fall relative to the segmental string – Bruce, 1977). Related to intonation, languages also exploit different pitch features to convey phrasal meanings. For example, the pitch cues for the statement/question distinction may vary across languages, with some languages resorting to final pitch height or direction (e.g., Dutch marks questions with a high boundary tone – Ladd, 2008, Chickasaw with a low boundary tone – Gordon, 2005, Japanese and EP with a rising boundary – Frota, 2002; Venditti, 2005, and Hungarian with a falling boundary – Ladd, 2008), others to peak alignment (such as Neapolitan Italian, where the pitch rise is timed later in questions than in statements - D'Imperio, 2002), and others to register expansion or reduction of downdrift (like Wolof – Rialland & Robert, 2001 - and Danish – Grønnum, 1992).

Similarly, the expression of focus distinctions by prosodic means was also found to vary across languages: higher peaks and wider pitch excursions may highlight important information in some languages (e.g., English), whereas other languages may use suspension of downdrift (e.g. Japanese), or pitch timing differences, typically with the peak aligned with the stressed syllable in the case of narrow/contrastive focus and either before or after the stressed syllable in the case of all-new information or broad focus (as in European Portuguese or Catalan – Gussenhoven, 2002, 2004; Vanrell, Stella, Fivela & Prieto, 2013). Duration differences are commonly found to be related to pitch differences in some languages (for example, in Italian, the syllable with the narrow focused pitch peak tends to be longer than its broad focus counterpart with no pitch peak - Vanrell et al., 2013).

Several studies have addressed the perception of some of these prosodic contrasts, and have shown that they are perceived by adult native speakers (e.g., D'Imperio & House, 1997;

Ladd & Morton, 1997; Gandour, Wong, Hsieh, Weinzapfel, Van Lancker & Hutchins, 2000; Kohler, 2005; Wu, Tu & Wang, 2011; Vanrell et al., 2013). However, to our knowledge, there are no infant studies on the perception of focus distinctions cued by prosody, and in particular addressing prosodic contrasts that rely on pitch timing as the main pitch feature.

Pitch timing is a dimension of intonation that crucially integrates pitch and duration. It involves the location of a pitch turning point with respect to some temporal domain, for example the syllable. Recent research on infants' perception of prosodic cues suggests that pitch and duration are processed differently. Infants at 7 months group syllables with variable pitch based on a high-low pitch pattern, but no grouping preferences were found when duration differs between syllables, unlike in adults (Bion, Benavides-Varela & Nespor, 2011). Also, both human infants and nonhuman animals group sound sequences into trochaic patterns based on pitch, but do not utilize duration as a cue to group sequences into iambic structures (de la Mora, Nespor & Toro, 2013). Furthermore, both English and Japanese infants show no preference for tones varying in duration at 5-6 months, but at 7-8 months a grouping preference emerges that mirrors the native language background (English infants showed a grouping preference for trochaic structures while Japanese infants showed no preference, similar to adult preferences – Yoshida, Iverson, Patel, Mazuka, Nito, Gervain & Werker, 2010), providing further evidence for later development of the perception of differences in duration relative to pitch differences.

Evidence that the perception of durational based contrasts may evolve later in development can be also seen in Japanese learning infants´ abilities to discriminate single/geminate contrasts. A single/geminate contrast is a phonemic distinction that is characterised by the duration of the obstruent (as well as other co-occurring cues), such as in /saka/ meaning hill vs. /sakka/ meaning author (Tsujimura, 2007*).* At 4 months infants do not show evidence of discriminating this contrast. At 11.5 months, they are able to distinguish single and geminate obstruents based on the durational property (at 9.5 months, they are able to distinguish this contrast but only in the presence of co-occurring cues – Sato, Kato & Mazuka, 2012). These results suggest an initial difficulty in processing durational contrasts that improves due to repeated exposure to the contrast and/or developing maturational factors.

The findings on infants' perception of word stress also suggest differences related to the nature of prosodic cues. Unlike for lexical pitch and intonation distinctions based on pitch height/direction, for which precocious discrimination abilities are found, word stress discrimination involves sensitivity gains during the first year of life, dependent on continued exposure to the native language and/or maturational factors, and similarly to findings on the perception of durational differences (Jusczyk, Cutler & Redanz, 1993; Höhle, Bijeljac-Babic, Herold, Weissenborn & Nazzi, 2009; Skoruppa, Pons, Christophe, Bosch, Dupoux, Sebastián-Gallés, Limissuri & Peperkamp, 2009; Skoruppa, Cristià, Peperkamp & Seidl, 2011; Bijeljac-Babic, Serres, Höhle & Nazzi, 2012; Skoruppa, Pons, Bosch, Christophe, Cabrol & Peperkamp, 2013).[1] Although the weighting of acoustic cues for stress is not detailed in most studies, in some languages stress contrasts are known to typically use to a greater extent phonetic cues other than pitch, in particular, vowel quality and duration cues (Beckman, 1986; Sluijter and van Heuven, 1996; Ortega-Llebaria, & Prieto, 2010; Chrabaszcz, Winn, Lin & Idsardi, 2014).

Taken together, these findings seem to suggest that pitch-based discrimination, pitch height and direction in particular, is more dependent on general perceptual abilities while the discrimination of duration contrasts is dependent on language experience and maturational factors. This raises interesting questions with respect to the developmental course of the

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[1] Very young infants have been shown to be sensitive to stress changes, as reported in Jusczyk & Thompson (1978) for English learning infants at 2 months. However, this ability was found in the absence of segmental variation in the stimuli (and in the presence of both pitch and duration cues for the stress difference), whereas segmentally varied stimuli were used in the studies with older infants where sensitivity gains is the dominant pattern for languages with contrastive stress.

perception of pitch timing distinctions. In European Portuguese (EP), the contrast that marks the distinction between all-new information, or broad focus, and the highlighting of a particular word, or narrow/contrastive focus, is primarily marked in declarative utterances by the timing of the pitch fall with respect to the stressed syllable of the nuclear word, that is the word that carries the primary or nuclear pitch accent (Frota, 2000, 2002; Fernandes, 2007; Frota, 2014; Frota, Cruz, Fernandes-Svartman, Vigário, Collischonn, Fonseca, Serra & Oliveira, in press). In the first case, the peak aligns just before the stressed syllable and the fall is fully realized within this syllable (a pitch temporal coordination with the stressed syllable that is annotated as H+L*, where the asterisk identifies the tone aligned with the stressed syllable), whereas in the second case the peak occurs on the stressed syllable followed by a fall to the post-tonic (annotated as H*+L). For example, the utterance "Casaram" (They got married), as a reply to "What about Roberto and Maria?", would exhibit the early peak melody (H+L*), but, as a response to "Have they split up?", would show the late peak melody (H*+L). In addition to the timing of the pitch fall, these two melodies are usually accompanied by duration and intensity differences (Frota 2000). The pitch timing contrast has been shown to be perceived by adult native speakers of EP, independently of the duration and intensity differences (Frota, 2012).

Although there are no studies on the use of prosodic focus in infant-directed speech (IDS) in European Portuguese, it can be assumed that IDS shows a fair proportion of highlighting of particular words expressing new information or contrastive information, as shown by Fernald and Mazzie (1991), who demonstrated that speech directed to English-learning infants regularly used pitch prominence to mark focused words. Given that in EP highlighting of such words under narrow/contrastive focus is associated with late timing of the pitch fall, whereas the nuclear word under broad focus displays early timing of the pitch fall, it is expected that infants are exposed to the pitch timing contrast early in development through IDS. In recent work on early intonational development in EP, it was found that toddlers are able to produce the pitch timing contrast, and use it in appropriate ways according to context (Frota, Matos, Cruz & Vigário, accepted). By and large, the early/late fall pitch cue seems to be quite robust in production and in adult perception of the prosodic contrast that differentiates between broad and narrow focus.

The presence of a duration-related pitch distinction in the prosody that cues the contrast between broad and narrow focus can lead us to two predictions. If perceptual abilities related to pitch contrasts in general show an early/precocious development (or are domain-general abilities, even across different species), we expect contrasts utilising pitch timing to behave as other types of pitch contrasts. Phonetic salience and distribution across languages may also link to differences in perceptual abilities (as suggested in Frota et al., 2014). Pitch contrasts have been shown to be especially salient and detected early by infants compared with other sound features (He, Hotson & Trainor, 2007; Bion et al., 2011), and some form of linguistic melody seems to be present in all languages, be it tone, lexical pitch accent or intonation (Gussenhoven, 2004), but the same is not necessarily true for stress (as there are languages with no apparent phonetic stress – Beckman, 1986) or for the phonemic use of duration. It is also known that there is a perceptual relation between pitch height and pitch timing (House, 1990; Gussenhoven, 2002), which has been demonstrated for adults: high peaks and late peaks are similarly perceived. If differences in pitch timing are generally equated to differences in pitch height in perception, we might expect an early sensitivity to pitch timing contrasts as well, and so no differences in age group would be evident.

On the other hand, pitch timing involves a duration-related distinction as well – the temporal location of the pitch turning point. This temporal property of the pitch contrast could lead to a protracted development of the perception of the broad / narrow focus prosodic distinction, in line with other findings on the perception of duration-based cues, and so would predict differences between age groups.

The main goal of the present study is to investigate the development of infants' perception of a prosodic contrast that cues the difference between all-new information (broad focus) and highlighting a particular word (narrow/contrastive focus), in EP. Using a visual habituation paradigm, we examined European Portuguese-learning infants' ability, at 7 and 12 months, to discriminate between the correlates of broad and narrow focus in the presence of phonetic variability. If early discrimination of the prosodic contrast is found, as it has been for previous findings on lexical pitch accent and other intonational contrasts, this will show that infants have a general perceptual advantage for discriminating pitch-based contrasts. If only older infants display a discrimination ability for this contrast, this would suggest that there are differing developmental trajectories for different kinds of prosodic features, as in the case of previously reported differences between stress on the one hand and lexical pitch and intonation on the other, or between pitch and duration. If an advantage for certain prosodic contrasts over others is evident, this has potential implications for the acquisition of the linguistic distinctions cued by prosody in a given language.

# Method

## Participants

Forty infants participated in this study, split into two age groups; 20 younger (10 female, mean age 6 months 28 days, range 6 months – 8 months 3 days) and 20 older (9 females, mean age 12 months 7 days, range 10 months 16 days – 14 months 6 days). All were normally developing infants raised in monolingual European Portuguese homes, recruited from the wider Lisbon area. In addition, 3 infants (2 younger, 1 older) were rejected from the study due to fussiness (1) and software error (2).

Materials

A set of 16 pseudo-words was used to create broad and narrow focus, segmentally varied, single-prosodic word utterances.[2] The pseudo words were tri-syllabic sequences with penultimate stress, produced by a female native speaker in IDS (darono, lunirra, pamolo, sinurra, tumela, dalemo, biloma, turano, quimola, rumilo, furina, silamo, marreno, pinorro, cunerra, faluma). With the exception of the first consonant, the sequences were all sonorant to maximize the conditions for pitch realization. Tri-syllabic words were used to allow for the presence of both a pre-tonic and a post-tonic syllable which provide the best segmental setting for the early/late fall contrast. Examples of the two stimuli types are shown in Figure 1.

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Insert Figure 1 here

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Mean fundamental frequency of the pitch fall and timing of the peak relative to the beginning of the stressed syllable, as well as duration and intensity values were computed for the broad and narrow focus stimuli (Table 1). Mean pitch values by syllable are also shown in Table 1.

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Insert Table 1 here

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[2] One-word utterances were used since this is the most common prosodic domain for a melody in EP infant-directed speech (Frota, Butler & Vigário, 2014).

As expected, the acoustic measurements showed a significant peak timing difference, with early timing of the peak (before the onset of the stressed syllable) in the broad focus stimuli and late timing of the peak (within the stressed syllable) for the narrow focus stimuli, together with duration and intensity differences (specifically, the pre-tonic syllable is longer in broad focus and thus the difference between pre-tonic and stressed syllables is larger in narrow focus, and the intensity of the stressed syllable is higher for narrow focus). The peak timing difference leads to higher mean pitch in the pre-tonic in broad focus (as this syllable bears the high tone) and higher mean pitch in the stressed and post-tonic syllables in narrow focus (given that the high tone is on the stressed syllable and thus the pitch in the post-tonic is still falling). In addition, narrow focus shows a wider pitch fall than broad focus, also in line with previous descriptions that point to the raising of the peak and the larger fall as an optional feature of the narrow focus contour (Frota, 2000).

In order to test whether the two stimuli types were suitable representatives of the broad/narrow focus contrast, 6 adult listeners were presented with exemplars of the broad and the narrow focus stimuli, and asked to rate them on a scale of 1 to 5, whether the exemplar heard was spoken in response to the question "what happened?" (equal to 1 on the scale) or "Have you said «*xiveto*»?", where "xiveto" is also a pseudo-word (equal to 5 on the scale). Five out of the 6 participants rated the stimuli appropriately (overall, broad focus mean – 1.78, narrow focus mean – 4.05).[3] A nonparametric Wilcoxon Signed Ranks test revealed a significant difference in responses to the two stimuli types ($z = 1.99$, $p < .05$). Responses to each item were also analysed, and all 16 items were rated appropriately (broad focus mean – 1.86, narrow

[3] One participant did not differentiate between the two types of stimuli. However, although residing in Lisbon for more than 10 years, this participant was a native speaker of a Southern variety of EP.

focus mean – 3.94). A paired T-Test revealed a significant difference in responses to the two stimuli types ($t(15) = 3.94$, $p < .001$, $d = 2.035$).

In addition to differences in intonation, different pseudo-words were used for habituation and test phases (half the stimuli for each: habituation trials - darono, lunirra, pamolo, sinurra, tumela, dalemo, biloma, turano; test trials - quimola, rumilo, furina, silamo, marreno, pinorro, cunerra, faluma). The sound files of the stimuli are available at http://ww3.fl.ul.pt/laboratoriofonetica/babylab/Infants_Perception/Infants_perception_pitch_timing_supporting_materials.htm.

Procedure

A modified version of the visual habituation paradigm (Best, McRoberts & Sithole, 1988; Polka & Werker, 1994; Stager & Werker, 1997) was used, which has been utilized for testing infants' discrimination (Sato et al., 2009; Mazuka, Cao, Dupoux & Christophe, 2011; Frota et al., 2014). Infants were seated on their caregivers lap facing a computer monitor, with speakers hidden behind the monitor. Each trial began with a colourful, attractive image to attract the infants' attention. Once the infant fixated the image, it was replaced with a red and black checkerboard display, and paired with the auditory habituation stimuli, presented through the speakers. The duration of each trial was 16 seconds, and consisted of 8 one-word utterances (in order to account for the differing durations of stimuli due to the difference between broad and narrow focus, the inter-stimulus-interval (ISI) was adjusted to ensure all trials were equal length, average ISI broad focus trials = 1359ms, narrow focus trials = 1401ms). Trials continued until all 8 utterances had been presented, and the next trial commenced with the colourful, attractive image. Habituation trials continued until a pre-set habituation criteria was reached (i.e., average looking times to the last four habituation trials heard was less than 60% of the first four habituation trials), or a total of 28 habituation trials had been presented. Habituation was followed by a test phase, where infants were presented with one "same" (as the habituation) test trial and one “switch” (different to the habituation) test trial. Infants were habituated to either broad or narrow focus intonation, with the order of test trials (same/switch first) also counterbalanced equally across infants. If sensitivity to the prosodic contrast is evident, infants should display longer looking times to the switch test trials.

Stimuli presentation was controlled by the LOOK software (Meints & Woodford, 2008), and an experimenter who observed the infant via a camera discretely placed above the monitor. Trials were initiated by pushing a button when the infant fixated the image, and the button push was maintained while the infant remained oriented to the image. The experimenter was blind to the experimental conditions, and both experimenter and caregiver wore music-playing headphones to mask stimuli presentation. Total looking time for each trial was monitored by the LOOK software, and automatically initiated the test phase when the habituation criteria was reached.

## Results

The behaviour of infants within the habituation phase of the experiment was analysed using a repeated measures analysis of variance (ANOVA) with a within-participant factor of habituation (beginning of habituation phase versus end of habituation phase) and two between-participant factors of age group (younger versus older) and habituation conditions (broad versus narrow focus). Overall, average looking times to the first four habituation trials (*M*-11.74, *SD*-2.77) were longer than looking times to the last four habituation trials (M-7.05, SD-2.66), and this pattern was also true for both younger (first four trials M-12.34, SD-2.47; last four trials M-7.43, SD-2.54) and older (first four trials M-11.13, SD-2.93, last four trials M-6.67, SD-2.74) groups. There was a significant effect of habituation ($F(1,36) = 1112.38$, $p < .001$, n2 = .97), and the age group effect was not significant (F(1,36) = 3.84, p = .06, n2= .1). All other effects and interactions were non-significant.

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Insert Figure 2 here

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Looking times in the test phase were investigated using a repeated measures ANOVA with a within-participant variable of trial type (same versus switch) and two between-participant variables of age group (younger versus older) and habituation condition (broad versus narrow focus). There were no significant main effects of trial type (F(1,36) = 2.34, p = .14, n2 = .06), age group (F(1,36) < 1) or condition (F(1,36) < 1). There was a significant interaction between trial type and age group (F(1,36) = 7.82, p < .01, n2 = .06), with no other significant interactions (trial type X condition - F(1,36) < 1, age group X condition - F(1,36) < 1, trial type X age group X condition – F(1,36) = 2.22, p = .15, n2 = .06). Paired t-tests for each age group separately showed no significant differences between same and switch trials for the younger group (t(19) = .85, p = .41, *d* = 0.194), but there was a significant difference for the older group (t(19) = 3.19, p < .01, *d* = 0.911). Average looking times for same and switch trials in the test phase are presented in Figure 2. As can be seen, only the older age group displays longer looking times to the "switch" test trials (younger same M-7.72, SD-3.47, switch M-7.1, SD-2.89; older same M-6.13, SD-2.34, switch M-8.24, SD-2.9). Overall, 7 out of 20 younger and 16 out of 20 older infants had longer looking times to the switch trials. Hence, at around 7 months infants were not able to discriminate between early and late pitch timing patterns, an ability that emerges by the end of the 1$^{st}$ year, by around 12 months.

## Discussion

In this study, we investigated young infants' perception of intonation by examining 7- and 12- month-old EP learning infants' discrimination abilities for the prosodic contrast between broad and narrow focus in their native language. We found evidence that infants were only able to successfully discriminate this contrast towards the end of the 1st year. Therefore, infants' sensitivity to the particular set of prosodic features that differentiate between broad and narrow focus is initially poor, with the ability to perceive this type of contrast developing after 7 months, and becoming evident by the end of the first year. As infants were presented with phonetically varied stimuli, successful discrimination is assumed to reflect their ability to extract the prosodic features that characterize broad and narrow focus utterances across segmental variation, an ability they demonstrated around the age of 12 months. These findings are in contrast with those previously reported for the intonation distinction in EP that differentiates statements and yes-no questions, where infants as young as 5-6 months were able to discriminate this sentence type distinction, and maintain this sensitivity throughout the first year (Frota et al., 2014). Importantly, the sentence type distinction is cued by a pitch height (low vs. high) and direction contrast (fall vs. fall-rise), accompanied by duration differences, whereas the broad and narrow focus distinction is cued by a pitch timing difference that involves the same contour, a pitch fall, accompanied by duration and intensity differences. This indicates different developmental trajectories for different kinds of intonation contrasts, rather than early general discrimination abilities for pitch contrasts. Since a discrimination ability may be regarded as a prerequisite for the acquisition of a linguistic distinction that is cued by prosodic means, our findings suggest an advantage of certain prosodic cues over others with potential implications for the acquisition of linguistic categories marked with different prosodic features within and across languages.

As the prosodic contrast that differentiates between broad and narrow focus in EP is primarily marked by the timing of the pitch fall with respect to the stressed syllable, that is the temporal location of the pitch turning point (Frota, 2000, 2002; Fernandes 2007; Frota, 2014;

Frota et al., in press), these findings add further evidence that infants initially process duration related contrasts differently from non-temporal pitch-based contrasts, such as pitch height/direction, and that in fact duration related contrasts are not successfully processed until later in development (Yoshida et al., 2010; Bion et al., 2011; Sato et al. 2012; de la Mora et al., 2013). In the context of infants development of the perception of prosodic contrasts generally, our findings place the perception of broad and narrow focus prosody along a similar path to that found for stress-based contrasts (Jusczyk et al., 1993; Höhle et al., 2009; Skoruppa et al., 2009; Skoruppa et al., 2011; Skoruppa et al., 2013), and unlike that of lexical pitch accent and lexical tone (Mattock & Burnham, 2006; Mattock et al., 2008; Sato et al., 2009; Yeung et al., 2013), as well as intonation contrasts based on pitch height and pitch direction (Frota et al., 2014). These results suggest that infants' abilities to perceive a prosodic contrast are dependent on the types of acoustic cues that define the contrast. Infants seem to show a precocious ability to perceive contrasts based on pitch height or direction (whether at the lexical or phrasal level), while stress contrasts develop along with language experience and/or maturational factors. Stress contrasts may use duration cues, together with pitch or to a greater extent than pitch, at least in the languages examined in infant perception studies (Beckman, 1986; Cutler, 2005; Ortega-Llebaria & Prieto, 2009). Our findings on the perception of the prosodic distinction between broad and narrow focus, which includes a pitch timing difference, thus show that the ability to perceive pitch differences cannot be taken as a general ability that characterizes infant speech perception.

Similarly, it does not seem to be the case, as suggested by Frota et al. (2014), that the differences in perceptual abilities in early development for different prosodic contrasts may be explained by phonetic salience and distribution across languages. Pitch contrasts have been shown to be especially salient and detected early by infants compared with other sound features (He et al., 2007; Bion et al., 2011), and some form of melody seems to be present in all languages (Gussenhoven, 2004). Together with pitch height and direction, pitch timing is one of the dimensions on which pitch can vary to signal meaning. In fact, pitch timing is a form of pitch contrast that is common across languages (e.g., lexical pitch accent distinction in Swedish, intonation contrasts described for Italian, Catalan, or German – Bruce, 1977; D'Imperio, 2002; Kohler, 2005; Vanrell et al., 2013), and perceptually pitch timing differences have been equated to pitch height differences in adults' perception: early peaks behave as low peaks and late peaks as high peaks (House, 1990; Gussenhoven, 2002). Importantly, there is a tendency for the highlighting of information (narrow/contrastive focus) to be signalled by peak height or peak timing and pitch excursion size across languages (Gussenhoven, 2002, 2004). Although more research is needed, there is in principle no reason to expect pitch timing contrasts to be less salient or less frequent than other kinds of pitch contrasts. We would like to suggest that the protracted development of broad/narrow focus discrimination links to the temporal properties of the particular kind of pitch cues involved (i.e., a contrast in the temporal location of the pitch turning point within the syllable), in line with other findings on infants' perception of duration that point to a need of more extensive language experience.

However, before it can be concluded that there are different developmental trajectories for the perception of different kinds of prosodic contrasts (e.g, stress, lexical tone, lexical pitch accent, sentence type intonation, focus intonation) depending on the acoustic cues that realize that contrast, we should ask whether methodological reasons might explain the differences found in perceptual abilities across prosodic contrasts, and across studies. Most studies of infants' perception of prosodic categories have used variants of the head-turn preference procedure (Mattock & Burnham, 2006, for lexical tone; Höhle et al., 2009 for stress), in some cases with visual and auditory presentation (Skoruppa et al., 2009, 2013, for stress), or some version of the visual fixation/habituation paradigm (Sato et al., 2009, for lexical pitch accent; Soderstrom et al., 2011, Frota et al., 2014, for intonation; Yeung et al., 2013, for lexical tone).

By and large, in these studies infant listening is indexed to visual fixation/orientation, and discrimination is obtained by longer looking time to novel trials compared to the familiar or habituation trials. A similar procedure was utilised in the current study (which was identical to that used, for example, in Sato et al., 2009 and Frota et al., 2014). More variation across studies is found in the types of stimuli used, that may be crucially dependent on the languages and/or prosodic contrasts under examination. For example, lexical tone studies typically use CV syllables as stimuli since words in the relevant languages are mainly monosyllabic, whereas studies on lexical pitch accent, stress and intonation contrasts have used disyllabic or (though more rarely) trisyllabic tokens. In a study of newborns' discrimination of stress patterns, Sansavini (1997) found a similar pattern of discrimination for disyllabic and trisyllabic pairs of words (with varied consonants, but not varied vowels). Frota et al. (2014) used segmentally varied (both consonants and vowels) disyllabic utterances in their study, and found infants at 5-6 months could discriminate an intonation contrast based on pitch height/direction. It was necessary to use trisyllabic utterances in the present study as it provided the optimal environment in order to facilitate the early/late fall characteristic of the broad/narrow focus contrast. Although Sansavini's (1997) findings with newborns suggest that 7-month olds might be able to deal with trisyllabic tokens, it is possible that the failure of the younger infants in the present study could be due to the more complex, segmentally varied trisyllabic utterances, and potentially younger infants in Frota et al.'s study may also have failed under similar conditions. Alternatively, it may be the case that early discrimination abilities in the absence of phonetic variability (i.e. a single token with contrasting prosodic realizations) are found for the broad/narrow focus distinction, similarly to findings for stress (Friederici, Friedrich, & Christophe, 2007; Höhle et al., 2009; Skoruppa et al., 2013), whereas results for lexical pitch accent or intonation contrasts based on pitch height/direction show that early discrimination abilities are not hindered by phonetic variability (Nazzi, Floccia & Bertoncini, 1998; Sato et al., 2009; Frota et al., 2014). In order to ascertain how stimuli complexity affects early perceptual abilities, further research is required with intonation contrasts, and also lexical pitch.

In conclusion, the present findings that EP learning infants are only able to discriminate the intonation contrast marking broad and narrow focus declarative utterances by 12 months, but not around 7 months, adds to our knowledge of how the perception of prosodic contrasts develops by extending previous research into the intonation contrasts that express information status. This study demonstrates the seemingly different developmental trajectories of the perception of different prosodic contrasts, highlighting the importance of the nature of the cues that signal a given contrast in a given language.


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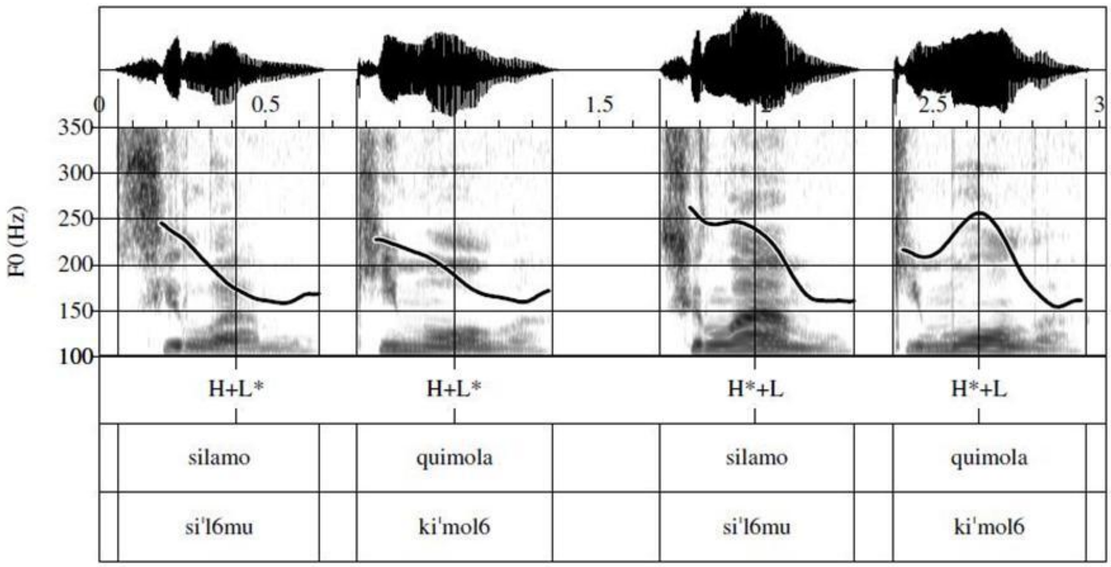


Figure 1: Intonation contours of broad (left two examples) and narrow (right two examples) focus, with prosodic labelling and orthographic and phonetic transcription (in SAMPA).

Table 1: Acoustic analysis of the stimuli.

| | | *Broad* | | *Narrow* | | *t-test* |
|---|---|---|---|---|---|---|
| | | *Mean* | *ST Dev* | *Mean* | *St Dev* | |
| Pitch fall (Hz) | | 68 | 9.66 | 90 | 8.69 | 7.52, $p < .001$ |
| Peak timing (ms) | | -29 | 7.95 | 140 | 32.24 | 22.12, $p < .001$ |
| Mean pitch values (Hz) | Pre-tonic | 228 | 9.42 | 222 | 12.01 | 3.34, $p < .05$ |
| | Stressed | 195 | 7.37 | 233 | 6.57 | 18.61, $p < .001$ |
| | Post-tonic | 168 | 4.81 | 173 | 5.75 | 4.02, $p < .01$ |
| Duration (ms) | Pre-tonic | 159 | 43.81 | 101 | 21.70 | 6.95, $p < .001$ |
| | Stressed | 254 | 34.66 | 262 | 22.67 | 1.22, $p = .24$ |
| | Post-tonic | 229 | 18.72 | 236 | 17.81 | 1.49, $p = .16$ |
| Intensity (dB) | Pre-tonic | 74 | 2.51 | 74 | 1.88 | .09, $p = .93$ |
| | Stressed | 72 | 2.11 | 75 | 0.81 | 6.83, $p < .001$ |
| | Post-tonic | 65 | 3.11 | 66 | 2.81 | 3.23, p< .01 |

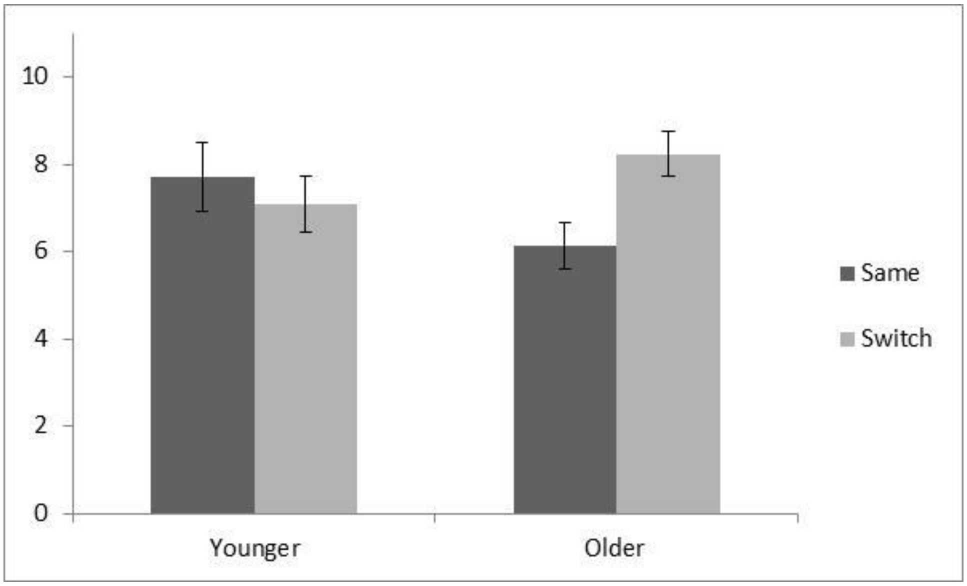


Figure 2: Average looking times (in seconds) to the same/switch test trials, across the two age groups. Error bars indicate the standard error of the mean (+/- 1)