



PAPER

Language-specific stress perception by 9-month-old French and Spanish infants

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Abstract

During the first year of life, infants begin to have difficulties perceiving non-native vowel and consonant contrasts, thus adapting their perception to the phonetic categories of the target language. In this paper, we examine the perception of a non-segmental feature, i.e. stress. Previous research with adults has shown that speakers of French (a language with fixed stress) have great difficulties in perceiving stress contrasts (Dupoux, Pallier, Sebastián & Mehler, 1997), whereas speakers of Spanish (a language with lexically contrastive stress) perceive these contrasts as accurately as segmental contrasts. We show that language-specific differences in the perception of stress likewise arise during the first year of life. Specifically, 9-month-old Spanish infants successfully distinguish between stress-initial and stress-final pseudo-words, while French infants of this age show no sign of discrimination. In a second experiment using multiple tokens of a single pseudo-word, French infants of the same age successfully discriminate between the two stress patterns, showing that they are able to perceive the acoustic correlates of stress. Their failure to discriminate stress patterns in the first experiment thus reflects an inability to process stress at an abstract, phonological level.

Introduction

Infants learn their native language with surprising rapidity. Their perceptual capacities have been shown to adapt to their mother tongue before their first birthday and before the production of their first words: For instance, while 6-month-old English infants have no problem in discriminating Salish ejectives and Hindi retroflex consonants, 12-month-olds perform at chance, just like English adults (Werker & Tees, 1984). Tuning to the native language has also been reported for vowel contrasts, occurring slightly earlier at 6 months (Kuhl, Williams, Lacerda, Stevens & Lindblom, 1992; Polka & Werker, 1994).

Languages differ not only in their segmental inventories, but also in their use of prosodic cues to convey differences in meaning. For example, tone languages such as Chinese use variations in pitch to distinguish among different lexical items. These pitch differences are hard to perceive for adult speakers of non-tonal languages such as English (Wang, Spence, Jongman & Sereno, 1999). A recent cross-linguistic study on tone perception in infants shows that between 6 and 9 months

of age, English infants' discrimination abilities decline compared to those of Chinese infants (Mattock & Burnham, 2006).

Another crucial aspect of prosody whose importance differs among languages is word stress. Stress can be used to differentiate word meaning in languages with contrastive lexical stress, such as Spanish. In this language, stress falls in a not fully predictable manner on one of the last three syllables of the word, and there are pairs of words that differ only as far as the position of stress is concerned, e.g. *l'bebel* = 'he/she drinks' – *lbe'bel* = 'baby'. In other languages, stress is fixed to a certain position. In French, for example, stress falls on the last syllable of each phrase. The distribution of stressed syllables in French is thus completely uninformative for lexical access. This difference between Spanish and French is reflected by the way in which stress is perceived by adult listeners: Native speakers of French have more difficulties in perceiving word stress than native speakers of Spanish (Dupoux, Pallier, Sebastián-Gallés & Mehler, 1997). The present study investigates the early tuning of stress perception to the native language.

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A number of studies have shown that infants are able to perceive the acoustic correlates of word stress from birth. These studies have typically used stimuli with very little variability (often just one single item). For instance, Italian newborns have been reported to discriminate different stress patterns in di- and trisyllabic pseudo-words (e.g. *'takalal* vs. *lta'katal*), and in lists of pseudo-words with consonantal variation (*'daga 'nata . . . l* vs. *l'da'ga na'ta . . . l*) (Sansavini, Bertocini & Giovanelli, 1997). Similarly, 2-month-old English infants can discriminate the stress patterns of disyllabic pseudo-words (*'bada 'gadal* vs. *lba'da ga'dal*) (Jusczyk & Thompson, 1978).

Infants exposed to a language with contrastive lexical stress have to process stress patterns not only at an acoustic level, but also at a more abstract, phonological level, since it is instantiated on many different vowels in the target language. Studies using more varied stimuli suggest that stress perception at this abstract level may not evolve until later: Thus, 6-month-old American infants do not show any preference between lists of disyllabic stress-initial words (e.g. *'orbit, barber, . . .*) and disyllabic stress-final words with matched vowels (e.g. *'aboard, bizarre, . . .*) (Jusczyk, Cutler & Redanz, 1993). It is only at 9 months of age that a preference for the predominant stress-initial pattern of English emerges.

In two experiments, the present study examines word stress perception at different levels of abstractness in 9-month-old learners of Spanish and French. If infants have already adapted their stress perception system to their native language by this age, then the Spanish- but not the French-learning infants should be able to perceive and discriminate the stress patterns of words with highly variable segmental content at an abstract level (Experiment 1). Furthermore, since infants are sensitive to the acoustic cues to stress since birth, we predict that French infants should be able to perceive and discriminate stress when tested with less varied stimuli (Experiment 2).

Experiment 1

Method

We used a modified version of the familiarization-preference procedure (Jusczyk & Aslin, 1995) derived from the head-turn preference procedure (Kemler-Nelson, Jusczyk, Mandel, Myers, Turk & Gerken, 1995). This method has been successfully used to study language discrimination (Bosch & Sebastián-Gallés, 2001) as well as vowel discrimination (Bosch & Sebastián-Gallés, 2003). We familiarized infants with one type of stimuli (either stress-initial or stress-final items); we then assessed their interest both for stimuli of the same type (with the same stress pattern as during familiarization) and for stimuli of the other type (with the opposite stress pattern). Discrimination is indexed by longer listening times for novel stimuli relative to familiar stimuli during the test phase.

Participants

Forty-eight healthy full-term infants participated in Experiment 1. Twenty-four infants were raised in monolingual French families and tested in Paris, France; 24 infants were raised in monolingual Spanish families and tested in Barcelona, Spain. According to parental report, daily exposure to the native language ranged from 80 to 100%. The infants' mean age was 8;28 months (range: 8;04 to 9;22 months). Thirty-seven additional infants were tested, but not included in the final sample because of crying, fussiness or disinterest in the screens (17 French, eight Spanish),¹ parental interference (seven French, one Spanish), or experimenter error (two French, one Spanish).

Material

Sixteen CVCV sequences were constructed, eight for familiarization and eight for test. None of the items were real words in either Spanish or French. They contained only phonemes that exist in French and Spanish, and that have similar phonetic realizations in both languages. The stimuli were pronounced in infant-directed speech by a female native speaker of Spanish (a French speaker would not have been able to realize both stress patterns appropriately). The eight CVCV pseudo-words for familiarization were recorded once with stress on the initial syllable (*'datu, 'sapi, 'kiba, 'nuki, 'latu, 'buki, 'luma, 'tikul*), to be used with one group of infants, and once with stress on the final syllable (*l'da'tu, sa'pi, ki'ba, nu'ki, la'tu, bu'ki, lu'ma, ti'kul*), to be used with the other group. The eight test phase stimuli (to be used in both groups) were recorded only once. Four of them had initial stress (*'lapi, 'naku, 'nila, 'tulil*), and the other four had final stress (*lki'bu, lu'ta, pi'ma, pu'kil*). Acoustic measurements revealed that stress was instantiated by differences in duration, intensity and pitch between stressed and unstressed vowels: stressed vowels were significantly longer (difference: 121 msec; $t(23) = 4.24$; $p < .001$), louder (difference: 7.0 dB; $t(23) = 7.89$; $p < .001$) and had higher mean pitch (difference: 64.3 Hz; $t(23) = 7.63$; $p < .001$) than unstressed vowels. Stressed vowels had an average duration of 276 msec, an average intensity of 83.3 dB and an average mean F0 of 267.9 Hz, whereas unstressed vowels had an average duration of 155 msec, an average intensity of 76.4 dB and an average mean F0 of 203.7 Hz.

¹ Infants who fixated the side screen for less than 2 sec during at least one test trial were excluded from the analysis. Note that the lack of discrimination in French infants might account for the higher attrition rate among French subjects. That is, the fact that they did not perceive any differences in the stimuli may have made the experiment more boring to them. Furthermore, the French infants were tested by two less experienced experimenters, a factor which is well known to increase rejection rate.

Procedure

Infants were tested in a single session lasting between 4 and 10 minutes. The experiment was conducted in a sound-attenuated laboratory room, with infants facing three screens on which colorful and animated geometric forms could be displayed. The two lateral screens were placed at 35° to the right and left sides, and had a loud-speaker hidden below them to play the auditory stimuli. Visual and auditory presentation was controlled by a computer in an adjacent control room. Infants' looking behavior was recorded by a camera situated above the central screen, connected to a video-recorder and a TV in the control room. An experimenter unaware of the material that was currently presented monitored infants' looks to the three screens via the TV. She recorded the infants' looking times on-line via the computer.

Infants were tested on their parent's lap. The parent listened to masking voices through sound-proof headphones during the experiment.

Each trial started with a bright image on the central screen; as soon as the infant fixated it, the image disappeared, and another colorful image was displayed on one of the lateral screens. While the infant was fixating it, a list of auditory stimuli was played until the infant ceased to look at the side screen for more than 2 seconds or until trial completion, which occurred after three repetitions of the stimuli list. All fixation periods to the side screen were summed up as 'total looking time'.

Infants were randomly assigned to the 'stress-initial' or the 'stress-final' group. During familiarization, infants in the stress-initial group heard two familiarization lists containing four stress-initial pseudo-words each (*'datu, 'sapi, 'kiba, 'nukil* and *'latu, 'buki, 'luma, 'tikul*); similarly, the stress-final group heard two lists of four stress-final pseudo-words (*dda'tu, sa'pi, ki'ba, nu'kil* and *lla'tu, bu'ki, lu'ma, ti'kul*). Both lists were presented in alternation from the right and left side until infants accumulated 1 minute of total attention time for each list. If the infant got fussy, a short break could be taken at the beginning of this period.²

The four-trial test phase was identical for all infants. There were two trials with a list of new stress-initial pseudo-words (*'lapi, 'naku, 'nila, 'tulil*) and another two with a list of new stress-final pseudo-words (*lki'bu, lu'ta, pi'ma, pu'ki*). The order and side of presentation of the two lists were randomized, with the constraint that the first two test trials were different. Note that although all infants were presented with the same test stimuli, their familiarity with the stress patterns of the test lists depended on the type of stimuli heard during familiarization: For infants in the stress-initial group the stress-initial test list followed the pattern heard in familiarization ('same trial'), whereas the pattern of the stress-final test

list was new to them ('switch trial'). The reverse was true for infants in the stress-final group. Since test and familiarization stimuli differed in their segmental content, recalling particular tokens could not help infants in differentiating between the two test lists. Instead, infants had to group stimuli together into classes of stress pattern in order to notice the difference between 'same' and 'switch' trials.

Results

Looking times were recoded off-line frame by frame using the video-tapes of the test phase. Figure 1 (left) shows mean looking times per language group and test trial type. An ANOVA with the within-subject factor 'trial type' ('same' vs. 'switch') and the between-subject factors 'language' (Spanish vs. French) and 'familiarization group' (stress-initial vs. stress-final) revealed a main effect of trial type ($F(1, 44) = 5.39; p = .025$, difference 2.04 sec, $\eta^2 = 0.11$) and a marginal interaction between the factors 'language' and 'trial type' ($F(1, 44) = 3.30, p = .076$, difference 3.19 sec, $\eta^2 = 0.07$). There were no main effects of 'language' ($F(1, 44) < 0.01, p = .98$, difference 0.05 sec) or 'familiarization group' ($F(1, 44) = 0.68, p = .41$, difference 1.38 sec), and no interaction between 'language' and 'familiarization group' ($F(1, 44) = 0.54, p = .47$, difference 2.33 sec), between 'trial type' and 'familiarization group' ($F(1, 44) = 1.20, p = .28$, difference 1.93 sec) or between all three factors ($F(1, 44) = 0.87, p = .35$, difference 3.28 sec).

Paired *t*-tests were carried out for each language group separately. They revealed that Spanish infants' looking times during 'switch' trials were significantly longer than those during 'same' trials ($t(23) = 2.73, p = .01$, difference 3.64 sec, Cohen's $d = 0.57$, medium effect

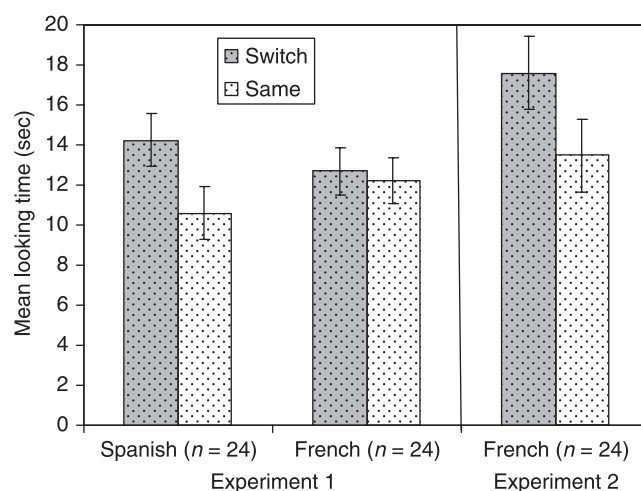


Figure 1 Mean looking times of Spanish and French infants for 'switch' and 'same' trials in Experiments 1 and 2. Error bars represent the standard error of the difference ('switch' vs. 'same').

² Only four infants that had taken a short break were included in the final analyses, the others having become very fussy again during the test phase.

size), whereas French infants showed no significant looking time differences ($t(23) = 0.38, p = .70$, difference 0.44 sec).

Furthermore, in order to check for baseline listening differences between the two infant groups, the number of trials needed by each infant to accumulate the necessary 2 minutes of listening time to complete the familiarization phase was analyzed by an ANOVA with between-subject factors 'language' (Spanish vs. French) and 'familiarization group' (stress-initial vs. stress-final). There were no main effects ('language': $F(1, 44) = 1.07; p = .31$, difference 0.7 trials; 'familiarization group': $F(1, 44) = 0.30, p = .59$, difference 0.4 trials) and no interaction ($F(1, 44) = 0.83, p = .37$, difference 0.7 trials).

Discussion

The Spanish infants showed a significant novelty preference in the test phase, indicating that they successfully discriminated the two stress patterns. French infants, by contrast, showed no differences in looking time according to stress pattern, and thus no sign of discrimination. The overall amounts of looking time during the test phase did not differ between the Spanish and French infants; hence, the French infants' absence of preference during the test phase cannot be attributed to generally shorter looking times (due to non-linguistic factors such as boredom). Furthermore, the observed effects are independent of the stress pattern infants were familiarized with.

The two language groups differ significantly in their perception of stress in pseudo-word lists at 9 months, suggesting that exposure to their native language has already altered their stress perception abilities. However, before we conclude that the French infants' difficulties stem from an abstract stress perception 'deafness' similar to the one found in French adults (Dupoux *et al.*, 1997), we should rule out two alternative explanations. First, French infants might have low-level phonetic difficulties with the perception of stress. Second, they might have global perception difficulties with stimuli that are produced by a Spanish speaker. The next experiment addresses both issues, using different realizations of a single pseudo-word to test for French infants' sensitivity for the acoustic correlates of stress produced by a non-native speaker.

Experiment 2

Method

Participants

Twenty-four healthy full-term infants raised in a monolingual French environment that had not participated in Experiment 1 took part in Experiment 2. Their mean age was 9;06 months, ranging from 8;05 months to 9;12 months. There were no significant age differences

between the French subjects of Experiment 1 and those of Experiment 2. Twenty-seven additional infants were tested, but not included in the final sample because of crying, fussiness or disinterest in the screens ($n = 21$),³ parental interference ($n = 2$), experimenter error ($n = 3$) and extremely high looking times ($n = 1$).⁴

Material

Twenty-four tokens of one of the pseudo-words used in Experiment 1, 'pima', were recorded in infant-directed speech by the same Spanish speaker who recorded the stimuli for Experiment 1. The speaker produced 12 tokens with initial stress (*'pimal*) and 12 with final stress (*l'pimal*). Acoustic measurements indicated that acoustic cues for stress were similar to those of Experiment 1: Stressed vowels were significantly longer (difference: 1.3 sec; $t(23) = 4.29; p < .001$), louder (difference: 5.8 dB; $t(23) = 6.92; p < .001$) and higher (difference: 64.1 Hz; $t(23) = 6.73; p < .001$) than unstressed vowels. No significant differences between the vowels used in Experiments 1 and 2 were found (duration: $p = .93$, intensity: $p = .19$, pitch: $p = .68$). The stimuli were divided into four familiarization and two test lists with consistent stress patterns.

Procedure

The procedure was identical to that of Experiment 1.

Results

Looking times were recoded as in Experiment 1. Mean recoded looking times per trial type are shown in Figure 1 (right). An ANOVA on recoded looking times with the within-subject factor 'trial type' ('same' vs. 'switch') and the between-subjects counterbalancing factor 'familiarization group' (stress-initial vs. stress-final) revealed a significant main effect of 'trial type' ($F(1, 22) = 5.26, p = .032, \eta^2 = 0.19$): infants listened longer to 'switch' trials than to 'same' trials (difference 4.1 sec). There was no main effect of 'familiarization group' ($F(1, 22) = 0.03, p = .87$, difference 0.39 sec) and no interaction ($F(1, 22) = 1.61; p = .22$, difference 4.57 sec).

Discussion

French infants showed a significant novelty effect, that is, a clear sign of discrimination of the two different stress patterns. It can be concluded that their inability to discriminate stress patterns in Experiment 1 was neither

³ We hypothesize that the high attrition rate in this experiment can be due, at least in part, to the monotony of the single pseudo-word paradigm.

⁴ Infants who could not disengage their attention and fixated the side screens longer than 28 sec in every test trial were excluded from the analysis.

due to difficulties with the perception of stress cues at an acoustic level nor to difficulties with the perception of stimuli pronounced by a non-French speaker.⁵

General discussion

At the age of 9 months, French and Spanish infants' abstract stress perception abilities are already tuned to their native language: Spanish infants, whose native language has contrastive lexical stress, spontaneously keep track of stress patterns when listening to pseudo-words. However, French infants, whose native language has fixed stress, ignore this prosodic dimension when listening to the same pseudo-words. Yet, when tested on a single pseudo-word, French infants do discriminate between different stress patterns.

These results are in line with those obtained in French adults, who generally have much more difficulties with the perception of stress contrasts than Spanish adults while their performances are as good as the Spanish ones if the stimuli show no phonetic variability at all (Dupoux, Peperkamp & Sebastián-Gallés, 2001). The present results, however, do not allow us to infer whether French infants, like adults, completely fail to *perceive* stress at an abstract, phonological level, or whether they rather have difficulties in *attending* to stress when presented with phonetically varied stimuli. This is because it is difficult to determine the exact nature of the task that infants perform in a head-turn preference paradigm. Either way, it is clear that French infants do not spontaneously encode stress phonologically when listening to new words, while Spanish infants do. Infants have thus already acquired knowledge about the role of stress in their language by 9 months of age.

How do infants adapt their perception of word stress to their native language so quickly? Since infants focus on supra-segmental units during the first months of life (Jusczyk, 1997), and since they are sensitive to the acoustic cues to word stress from birth (Sansavini *et al.*, 1997), it is possible that they start to analyze the stress patterns in the target language within the first trimester. Indeed, an ERP study provides evidence that 4- and 5-month-old German and French infants have already

tracked the frequency of stress patterns in their native language (Friederici, Friedrich & Christophe, 2007), with both groups showing brain potential variations only to the stimulus type which is rare in their native language: Infants learning German, a language with contrastive stress, but with a predominance of initial stress in disyllabic words, show a mismatch response if a pseudo-word stressed on the final syllable (*lba'bal*) is used as the deviant stimulus in an oddball paradigm. Conversely, infants learning French, a language with final stress, show a mismatch response if the stimulus stressed on the initial syllable (*'babal*) is used as deviant.

Subsequently, at 6 months of age, German infants prefer their native language's initial stress pattern when presented with stress-initial and stress-final realizations of a single pseudo-word (*'gabal* vs. *lga'bal*), whereas French infants do not show any preference at this age (Höhle, Bijeljac-Babic, Nazzi, Herold & Weissenborn, 2007). These results can be interpreted as first signs of a lack of interest for stress in French infants, but it is worth noting that 6-month-old French infants show discrimination of the same stimuli in a different task using a familiarization technique similar to ours (Höhle *et al.*, 2007), just as our 9-month-old French infants do when presented with a single pseudo-word. Thus, the lack of a preference does not seem to be informative as to the infants' stress perception abilities, which are better assessed with discrimination paradigms. This is in line with Pons and Bosch (2007), who report that 6- and 9-month-old Catalan and Spanish infants do not show any preference when they are presented with stress-initial and stress-final disyllabic pseudo-words, although they do discriminate these stress patterns. Concerning the lack of a preference for one of the stress patterns, Pons and Bosch (2007) observe that whereas Catalan and Spanish both have contrastive lexical stress, the predominance of stress-initial words among disyllables is less strong than it is in German and English. Contrastive stress thus appears to be a necessary but not a sufficient condition for a preference to be observed; there should also be a highly frequent default stress pattern.

To sum up, infants begin to tune their stress perception abilities to their native language by 4 to 5 months (Friederici *et al.*, 2007). At 6 months, infants learning a language with fixed stress pay less attention to stress contrasts than those learning a language with contrastive stress (Höhle *et al.*, 2007). Finally, the present study shows that by 9 months, infants' perception of stress at an abstract, phonological level is fully adapted to the native language: Spanish infants, who are learning a language where word stress can carry meaning, spontaneously encode it when listening to lists of pseudo-words; conversely, French infants, who are learning a language with fixed stress, do not encode it when listening to the same lists, although they are still sensitive to the acoustic properties of stress.

We conclude with some considerations concerning the underlying mechanisms that may lead to this rapid

⁵ To further check whether the Spanish stimuli we used were acceptable to French listeners, we had a French speaker parrot the Spanish stimuli, thus producing a new set of French disyllabic stimuli with the exact same stress characteristics as the Spanish ones. The French speaker recorded both the varied stimuli of Experiment 1 and the non-varied ones of Experiment 2. All stimuli, the Spanish ones used in Experiments 1 and 2 as well as the novel French ones, were presented to 12 native adult speakers of French and 12 native adult speakers of Spanish in a stress perception task similar to the one in Dupoux *et al.* (2001). It was found that the language of the speaker producing the stimuli had no influence on the participants' performance. These results show that the original Spanish stimuli and matched French stimuli were equally difficult to process for French and Spanish listeners, and that French infants' failure to discriminate in Experiment 1 cannot be attributed to the fact that they had to process foreign stimuli.

adaptation of stress perception to the native language. The status of stress in a given language, contrastive as in Spanish or fixed as in French, might be learnt in at least two different ways: First, infants might acquire it lexically, that is, by comparing the stress patterns of their lexical entries, after having segmented and stored a sufficient number of words. In light of the developmental pathway sketched above, this possibility seems unlikely, because until the age of 9 months, lexical knowledge and word segmentation abilities are very poor (for French infants, for instance, see Hallé & de Boysson-Bardies, 1994, and Nazzi, Iakimova, Bertoncini, Frédonie & Alcantara, 2006, respectively). Alternatively, Peperkamp and Dupoux (2002) propose a prelexical stress learning mechanism that analyses stress only at utterance boundaries, without taking word boundaries into account. As stress reliably falls on the last syllable of each utterance in French, analysing stress at utterance boundaries suffices to infer that stress is fixed on the final syllable. Given that in Spanish, words and hence utterances can be stressed on any of the last three syllables, it also allows infants to infer that Spanish has contrastive lexical stress. (Note, though, that it does not allow them to detect the predominant stress pattern of Spanish words.) Infants as young as 4 months show sensitivity to clause boundaries (Seidl & Cristià, 2008), making this learning mechanism a more plausible one. Further research using naturalistic corpus data, however, would be necessary to test its feasibility.

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