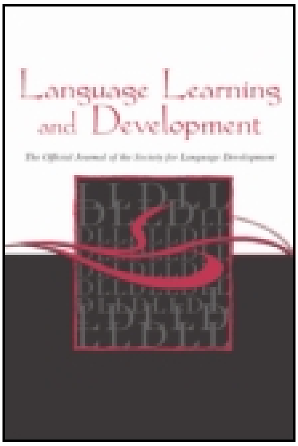

Language Learning and Development
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/hlld20

The Development of Word Stress Processing in French and Spanish Infants

Katrin Skoruppa [a] , Ferran Pons [b] , Laura Bosch [b] , Anne Christophe [c] , Dominique Cabrol [d] & Sharon Peperkamp [c]

[a] Department of Language and Linguistics, University of Essex

[b] Departament de Psicologia Bàsica and Institute for Brain, Cognition and Behaviour (IR3C), Universitat de Barcelona

[c] Laboratoire de Sciences Cognitives et Psycholinguistique (Ecole des Hautes Etudes en Sciences Sociales, Département d'Etudes Cognitives - Ecole Normale Supérieure, Centre National de la Recherche Scientifique), Paris

[d] Maternité Port-Royal, Université Paris Descartes

Version of record first published: 29 Nov 2012.

To cite this article: Katrin Skoruppa , Ferran Pons , Laura Bosch , Anne Christophe , Dominique Cabrol & Sharon Peperkamp (2013): The Development of Word Stress Processing in French and Spanish Infants, Language Learning and Development, 9:1, 88-104

To link to this article: http://dx.doi.org/10.1080/15475441.2012.693881

Language Learning and Development, 9: 88–104, 2013

ISSN: 1547-5441 print / 1547-3341 online
DOI: 10.1080/15475441.2012.693881

Routledge
Taylor & Francis Group

The Development of Word Stress Processing in French and Spanish Infants

Katrin Skoruppa

Department of Language and Linguistics, University of Essex

Ferran Pons and Laura Bosch

Departament de Psicologia Bàsica and Institute for Brain, Cognition and Behaviour (IR3C), Universitat de Barcelona

Anne Christophe

Laboratoire de Sciences Cognitives et Psycholinguistique (Ecole des Hautes Etudes en Sciences Sociales, Département d'Etudes Cognitives - Ecole Normale Supérieure, Centre National de la Recherche Scientifique), Paris

Dominique Cabrol

Maternité Port-Royal, Université Paris Descartes

Sharon Peperkamp

Laboratoire de Sciences Cognitives et Psycholinguistique (Ecole des Hautes Etudes en Sciences Sociales, Département d'Etudes Cognitives - Ecole Normale Supérieure, Centre National de la Recherche Scientifique), Paris

This study focuses on the development of lexical stress perception during the first year of life. Previous research shows that cross-linguistic differences in word stress organization translate into differences in word stress processing from a very early age: At 9 months, Spanish-learning infants, learning a language with variable word stress, can discriminate between segmentally varied nonsense words with initial stress (e.g., *níla, túli*) and final stress (e.g., *lutá, pukí*) in a headturn preference procedure. However, French infants, who learn a language with fixed word stress, can only distinguish between initial and final stress when no segmental variability is involved (Skoruppa et al., 2009). The present study investigates the emergence of this cross-linguistic difference. We show that at six months, neither Spanish nor French infants encode stress patterns in the presence of segmental variability (Experiment 1), while both groups succeed in the absence of segmental variability (Experiment 2). Hence, only Spanish infants, who learn a variable stress language, get better at

Correspondence should be addressed to Katrin Skoruppa, Department of Language and Linguistics, University of Essex, Wivenhoe Park, Colchester, Essex, CO4 3SQ, UK. E-mail: kskoruppa@gmail.com

tracking stress patterns in segmentally varied words between the ages of 6 and 9 months. In contrast, all infants seem to be able to discriminate basic stress patterns in the absence of segmental variability during the first nine months of life, regardless of the status of stress in their native language.

INTRODUCTION

Over the last decades, cross-linguistic research has unveiled many important facts about the way young children learn their native language. A number of studies have focused on perceptual adaptation to native sound categories within the second half of the first year of life, documenting both sensitivity losses for nonnative contrasts (Best & McRoberts, 2003; Best, McRoberts, LaFleur, & Silver-Isenstadt, 1995; Tsushima et al., 1994; Polka & Werker, 1994; Werker & Tees, 1984) and sensitivity gains for native contrasts (Kuhl et al., 2006; Narayan, Werker, & Beddor, 2010).

However, infants not only have to learn which segments are used contrastively, but they also have to determine the role of suprasegmentals in their native language. That is, infants have to find out which sound properties beyond segment identity, for instance, tones, length, and stress, can be used to distinguish lexical items. To date, few studies have investigated the developmental trajectory of infants' perception of suprasegmental structure. As far as tones are concerned, Mattock and Burnham (2006) observe that American infants' discrimination abilities for Thai tone contrasts (but not for nonspeech analogues) decline between 6 and 9 months of age, while Chinese infants' perception of the same stimuli remains stable. Thus, the discrimination of tonal contrasts decreases when this prosodic dimension is not used distinctively in the ambient language. This contrasts with the perception of vowel length, which involves a gain in sensitivity in infants learning Japanese, a language that uses this dimension distinctively: Sato, Sogabe, and Mazuka (2010) report that 4- and 7-month-old Japanese infants cannot discriminate between short and long vowels in nonsense words (*mana* vs. *maana*), but 9-month-olds can.

In the present study, we focus on stress, a suprasegmental that concerns the relative prominence of syllables in a word or utterance. Stress is central to language processing and acquisition: Both adults (Cutler & Norris, 1988; Vroomen, Tuomainen, & de Gelder, 1998) and infants (Jusczyk, Houston, & Newsome, 1999) rely heavily on stressed syllables in order to locate word boundaries, a prerequisite for vocabulary acquisition. Stress is also important for word recognition: Adult listeners are disrupted if words are pronounced with erroneous stress patterns (Soto-Faraco, Sebastian-Galles, & Cutler, 2001; Cooper, Cutler, & Wales, 2002; Small, Simon, & Goldberg, 1988; but see Cutler, 1986), and English-learning infants already pay attention to stress when learning new words at the age of 12 months (Curtin, 2009).

Unlike segmental contrasts, which can be acoustically subtle, stress has three salient phonetic correlates: stressed vowels are generally longer, louder, and have a higher F0 than unstressed ones (Fry, 1958). Like other suprasegmentals, stress can be used contrastively. In variable stress languages, such as English, German, and Spanish, stress can convey differences in meaning (e.g., English: *discount* (N.) [ˈdɪskaʊnt] vs. *discount* (V.) [dɪsˈkaʊnt]; German: *umfahren* [ʊmˈfaːʁən] 'to drive around' vs. *umfahren* [ˈʊmfaːʁən] 'to knock over' and Spanish: *saco* (N.) [ˈsako] - 'sack' vs. *sacó* (V.) [saˈko] - 'took out'). In fixed stress languages, stress always falls on the same position, for example, on the last syllable of words or phrases in French or on the first one in Hungarian. Thus, word pairs differing in stress only do not exist in these languages. These cross-linguistic differences are reflected in adult speakers' processing of stress: Spanish speakers, for instance, can track and memorize stress patterns of nonsense words, whereas French speakers find it difficult to perform this sort of task (Dupoux, Peperkamp, & Sebastián-Gallés, 2001).

Recent studies on word stress perception in infancy have yielded several important findings and raised a number of questions. It is widely accepted that infants can discriminate basic word stress patterns from birth, regardless of language background, as long as segmental variation in the stimuli is limited. Italian newborns can distinguish between initial and final stress in disyllabic nonsense words containing the same vowel (e.g., *dága náta* . . . vs. *dagá natá* . . .) in a high-amplitude sucking paradigm (Sansavini, Bertoncini, & Giovanelli, 1997). Similarly, French infants can discriminate stress-initial (e.g., *gába*) from stress-final (e.g. *gabá*) realizations of a single nonsense word in a head turn preference procedure at 6 months (Höhle, Bijeljac-Babic, Herold, Weissenborn, & Nazzi, 2009) and at 9 months (Skoruppa et al., 2009), although stress is not used contrastively in their native language.

However, efficient processing of word stress patterns in running speech requires the ability to track stressed syllables even if they contain a variety of different consonants and vowels. For such segmentally varied stimuli, successful discrimination has only been documented at 8 months for English-learning infants (Skoruppa, Cristià, Peperkamp, & Seidl, 2011) and at 9 months for Spanish-learning infants (Skoruppa et al., 2009). In both studies, infants were familiarized with either stress-initial (e.g., *níla túli* . . .) or stress-final (e.g., *lutá pukí* . . .) segmentally varied stimuli for two minutes and then preferred novel items with the opposite stress pattern over novel items with the familiarized pattern. Interestingly, infants learning French, a fixed stress language, did not discriminate these stress patterns in the presence of segmental variation at 9 months (Skoruppa et al., 2009). Taken together, these studies provide evidence for language-specific reorganization of word stress processing within the first 9 months of life. Specifically, by the end of that period, only infants learning a variable stress language (i.e., English or Spanish) track stress pattern contrasts efficiently in the presence of segmental variation. However, since stress pattern discrimination in segmentally varied words has not yet been tested in younger infants, it cannot be concluded whether it is infants learning a fixed stress language who learn to ignore word stress in the presence of segmental variation (as it is not needed to distinguish words in their native language) or whether it is infants learning a variable stress language who develop more robust and flexible stress processing skills, possibly by observing variability in stress patterns in the language they are exposed to.

Thus, the first experiment of the present study sets out to investigate French and Spanish infants' stress pattern discrimination in segmentally varied words at 6 months of age using the same method and stimuli as in Skoruppa et al. (2009). We expect both Spanish and French infants not to show any signs of discrimination at this young age, and we hypothesize that *learning*, rather than *unlearning*, is involved in the development of stress pattern encoding in the presence of segmental variation, since such learning effects have been shown for other sources of variability in other aspects of language processing.

Although variability seems to be advantageous in tasks involving word learning during the second year of life (Rost & McMurray, 2009, 2010), it generally presents a challenge for younger infants. For instance, 7.5-month-olds can only extract words from fluent speech when speaker gender (Houston & Jusczyk, 2000) and affect (Singh, Morgan, & White, 2004) are matched across familiarisation and testing. It is only at 10.5 months that infants can successfully segment words regardless of gender and affect variability. Between the ages of 9 and 12 months, they also learn to cope with dialect variation during word segmentation (Schmale, Cristià, Seidl, & Johnson, 2010).

In addition to speaker identity and affect, phonological context is also a source of variability that can increase processing difficulty for young infants. For instance, early prosody perception seems to be negatively affected by contextual variability: Shi's (2010) study suggests that 8- to 11-month-old, but not 4- to 6-month-old Chinese infants can perceive native tonal contrasts in syllables produced in different tonal contexts. Furthermore, a rule extraction experiment by Dawson and Gerken (2010) suggests that it may not be variability per se, but rather the number of competing dimensions that can prove problematic in early learning. Dawson and Gerken (2010) found that 4-month-olds could only extract a new pattern (AAB or ABB) if it was instantiated by vowels, not by CV syllables. Interestingly, 7-month-olds showed no such restriction.

To sum, a number of studies have shown that young infants find it difficult to cope with variability during language processing. These problems are likely to affect the early processing of word stress as well, on the one hand because the acoustic correlates of stress (duration, F0, and intensity) vary widely with the vowels involved and, on the other hand, because segmental content is a competing dimension that can divert infants' attention away from stress in word processing tasks.

Indeed, research on native word stress preferences suggests that segmental variation may be detrimental for stress processing early on. Using segmentally identical stimuli (e.g., *bába* vs. *babá*) with German- and French-learning infants, evidence for language-specific biases in stress perception has been found at the precocious age of 4 months in an electrophysiological paradigm (Friederici, Friedrich, & Christophe, 2007), and at 6 months in a behavioral head-turn preference procedure (Höhle et al., 2009). In the latter study, German 6-month-olds preferred stress-initial (*gába*) over stress-final realizations (*gabá*) of a single nonsense word. They are thus already biased toward initial stress, the predominant stress pattern in their native language. However, such a preference for initial stress, which is also the predominant stress pattern in English, only emerges between the ages of 6 and 9 months for segmentally varied stimuli in American infants (Jusczyk, Cutler, & Redanz, 1993; Turk, Jusczyk, & Gerken, 1995). Spanish infants likewise prefer the most frequent stress patterns of their native language in segmentally varied nonsense words at 9 months (Pons & Bosch, 2010). These findings lend themselves to the conjecture that word stress discrimination abilites may also develop later for segmentally varied stimuli than for segmentally identical stimuli. In the present study, we hence expect both Spanish and French 6-month-olds to fail at discriminating stress patterns in segmentally varied stimuli in our first experiment. In our second experiment, we also test their discrimination of segmentally identical stimuli and expect both language groups to succeed, just as French and German 6-month-olds did in a similar study (Höhle et al., 2009).

EXPERIMENT 1

Method

Participants. Thirty French infants (16 girls, 14 boys, mean age 6;04 months, range 5;26–6;13 months) were tested in Paris, and 30 Spanish infants (15 girls, 15 boys, mean age 6;04 months, range 5;17–6;16 months) were tested in Barcelona. All infants were healthy, born at full term and raised in monolingual families. According to parental report, mean percentage of daily exposure to the native language ranged from 100% to 80%. An additional 38 infants

TABLE 1
Stimuli in Experiment 1

Familiarization				*Test*	
stress-initial group		*stress-final group*		*all infants*	
list 1	*list 2*	*list 1*	*list 2*	*stress-initial list*	*stress-final list*
dátu	látu	datú	latú	lápi	kibú
sápi	búki	sapí	bukí	náku	lutá
kíba	lúma	kibá	lumá	níla	pimá
núki	tíku	nukí	tikú	túli	pukí

were tested but not included in the final sample because of crying, fussiness or disinterest in the screens[1] (11 French, 10 Spanish), parental interference (5 French), or experimenter error (10 French, 2 Spanish).

Stimuli. The stimuli, listed in Table 1, were the same as in the first experiment in Skoruppa et al. (2009). Sixteen CVCV sequences that had no meaning in French or in Spanish were used. They contained only phonemes that exist both in French and Spanish, and that have similar phonetic realizations in both languages. The stimuli were grouped into lists of four items each, as shown in Table 1. Half of them, those used for familiarization, had been recorded twice, once with initial stress and once with final stress. The remaining test items had been recorded once, four with initial stress and four with final stress.

All items had been produced in infant-directed speech by a female native-speaker of Spanish. Acoustic measurements revealed that stress was instantiated by significant differences in duration, intensity, and pitch between stressed and unstressed vowels (all ps $< .001$); further details can be found in Skoruppa et al. (2009).

Procedure. We used a variant of the head-turn preference procedure (Hirsh-Pasek et al., 1987) with a familiarization phase, as in Bosch and Sebastián-Gallés (2001). Infants were tested for 5–10 minutes in a dimly lit, sound-attenuated booth. A caregiver, who listened to masking voices through sound-attenuated headphones throughout the experiment, was seated in the middle of the room and held the infant on her lap.

The infant was facing three screens, one central and two lateral ones, on which colorful and animated geometric forms could be displayed. The lateral screens were placed at 35° to the left and to the right of the infant. Two loudspeakers were hidden below them to play the auditory stimuli. There was a TV camera above the central screen through which infants' looking behavior was monitored by an experimenter in an adjacent control room, who was unaware of the material presented. Visual and auditory presentation was controlled and infants' looking times were registered through a computer in the control room.

[1] Infants who had total looking times of less than 2 seconds during at least one test trial were excluded from analysis.

Each trial began with a bright image on the central screen. As soon as the infant fixated this screen, the image disappeared and another colorful image was displayed on one of the lateral screens. When the infant looked at it, a list of four auditory stimuli was played until the infant looked away from the side screen for more than two seconds or until the stimulus list had been repeated three times. The Stimulus Onset Asynchrony was fixed at 2.5s. All fixation periods to the side screen were summed up as "total looking time" for each trial.

During familiarization, half of the infants heard the two stress-initial lists; the other half heard the two stress-final lists. Presentation sides and lists alternated until the infant had accumulated one minute of total looking time for each list. The subsequent test phase was identical for all infants and consisted of four trials, two with novel stress-initial and two with novel stress-final items. The order and side of presentation of the test lists were randomized. Looking times during test phase were recoded off-line frame by frame on videotapes by an observer who was unaware of the stimuli presented.

Results and Discussion

Figure 1 (left) shows mean looking times by stress pattern for both language groups.[2] In order to compare their discrimination performance, we ran a repeated-measure ANOVA on infants' individual looking time means with the within-subject factor Stress Pattern (familiar vs. novel)

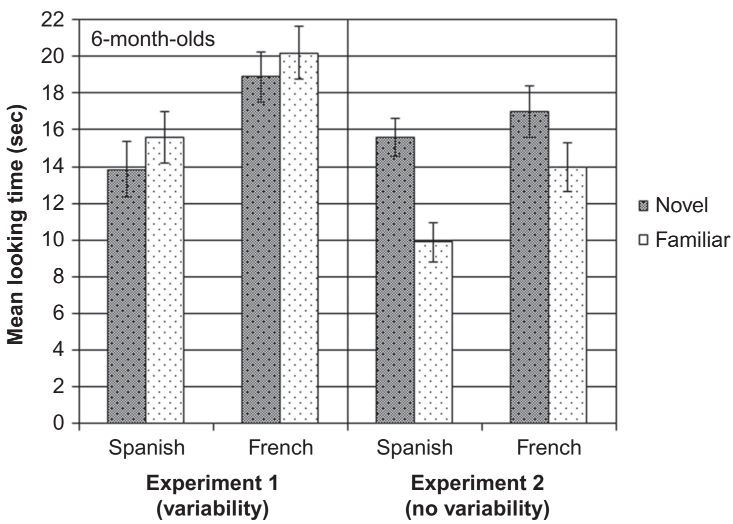

FIGURE 1 Mean looking times by language and by stress pattern in Experiments 1 and 2. Error bars represent +/− 1 Standard Error.

[2] Individual results can be found in the Appendix. Tables A1.1 and A1.2 show each infant's mean looking times for familiar and novel trials.

and with the between-subject factors Language (French vs. Spanish) and Familiarization (stress-initial vs. stress-final). We found a significant effect of Language only (mean Spanish: 14.7s vs. mean French: 19.6s, $F(1,56) = 8.49$; $p = .005$). Crucially, there were no effects or interactions involving the factor Stress Pattern. Thus, although French infants listen longer to the test stimuli overall than Spanish infants (possibly because they sounded foreign to them), the nonsense words' stress patterns did not influence listening times in either group. Hence, at 6 months, neither French nor Spanish infants discriminate between initial and final stress in varying nonsense words in our task.

To investigate developmental effects, the 6-month-olds' results in this experiment were compared to those of the 9-month-olds (see Figure 2, left) tested with the same method in Experiment 1 of Skoruppa et al. (2009). Because of differences in sample size ($n = 30$ per group at 6 months and $n = 24$ per group at 9 months), we performed a mixed-effect linear regression rather than an ANOVA. Using SPSS version 20.0.0 (IBM SPSS Statistics), we ran a Generalized Linear Mixed Model (GLMM), with Language, Age, and Stress Patterns as fixed effects. In this and in all following GLMM analyses, we controlled for participants and the interaction with the within-subject factor Stress Pattern in the random effect structure, we used a Satterthwaite approximation to account for differences in sample size across ages, and a robust estimation of the covariances to account for our small sample sizes (Maas & Hox, 2004). Full details of the fixed effect parts of the models can be found in Tables A1.3–A1.5 in the Appendix.

This analysis revealed a significant effect of Age (6 months: 17.1s vs. 9 months: 12.4s, $F(1,106) = 17.12$, $p < .001$) and Language (French: 16.4s vs. Spanish: 13.7s, $F(1,106) = 4.62$, $p = .034$) and significant interactions between Language and Age ($F(1,106) = 4.44$, $p = .037$) and between Age and Stress Pattern ($F(1,208) = 6.73$, $p = .010$). To further investigate these language- and age-related looking time differences, we also analyzed both language

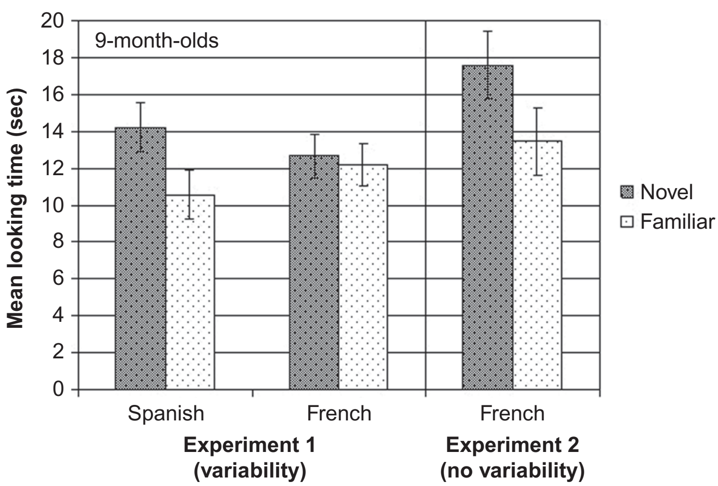

FIGURE 2 Mean looking times by language and by stress pattern for 9-month-old infants, adapted from Skoruppa et al. (2009). Error bars represent +/− 1 Standard Error.

groups separately, using a model with the fixed factors Age and Stress Pattern. For French infants, this analysis revealed a significant effect of Age only (6 months: 19.6s, 9 months: 12.5s, $F(1,57) = 20.38$, $p < .001$). Thus, although French infants show less interest in the stimuli overall at 9 months than at 6 months, this does not interact with their discrimination abilities for their stress patterns. For Spanish infants, the same analysis yielded a significant interaction between Stress Pattern and Age only ($F(1,104) = 7.65$, $p = .007$). This reflects the fact that Spanish 9-month-olds discriminated between stress patterns (familiar: 10.6s, novel: 14.2s, $t(23) = 2.73$, $p = .024$), while Spanish 6-month-olds did not (familiar: 15.6s, novel 13.8s, $t(29) = 1.19$, $p = .488$), as shown by paired two-tailed t-tests (Bonferroni-corrected). Hence, Spanish infants' abilities to track stress in varying nonsense words improve between the ages of 6 and 9 months.

Neither French nor Spanish infants show signs of stress pattern discrimination for segmentally varied nonsense words at 6 months of age in our paradigm. This contrasts with Spanish infants' abilities at 9 months, where a novelty preference indicated successful discrimination of the same stimuli (Skoruppa et al., 2009). No development was found in the French group. This suggests that only infants learning variable stress languages develop robust word stress processing abilities, although such cross-linguistic comparisons should be made with caution due to the absence of a significant three-way-interaction between Stress Pattern, Language, and Age in the global analysis.

Before drawing conclusions, it is also necessary to ensure that our testing procedure is valid at 6 months of age and that both French and Spanish infants are sensitive to stress patterns in nonsense words without segmental variation. Therefore, in the next experiment we use the same task that French 9-month-olds successfully mastered in Skoruppa et al. (2009), using stimuli without segmental variation. Both German and French 6-month-olds have shown sensitivity to stress pattern differences in experiments using multiple recordings of a single nonsense word (*gaba*) by a German speaker (Höhle et al., 2009); we thus expect French and Spanish 6-month-olds to succeed in this task as well.

EXPERIMENT 2

Method

Participants. Thirty French infants (14 girls, 16 boys, mean age 6;02 months, range 5;11–6;13 months) and 30 Spanish infants (15 girls, 15 boys, mean age 6;03 months, range 5;15–6;16 months) with the same characteristics as in Experiment 1 participated. An additional 45 infants were tested but not included in the final sample because of crying, fussiness, or disinterest in the screens (21 French, 15 Spanish), parental interference (2 French), or experimenter error (5 French, 2 Spanish).

Stimuli. The stimuli were the same as in the second experiment in Skoruppa et al. (2009). Twenty-four tokens of a single nonword (*pima*) had been recorded by the same Spanish speaker as in Experiment 1. Twelve were produced with initial stress (*píma*) and 12 with final stress (*pimá*). There were significant differences in duration, intensity, and pitch between stressed and unstressed vowels (all ps$<.001$), and these measures were not significantly different from the ones in Experiment 1 (all ps$>.1$). As before, the stimuli were divided into four familiarization and two test lists, each with consistent stress patterns.

Procedure. The procedure was the same as in Experiment 1.

Results and Discussion

Looking times, displayed in Figure 1 (right),[3] were analyzed as in Experiment 1. In the ANOVA with the factors Stress Pattern, Language and Familiarization, there was a significant effect of Stress Pattern (familiar: 11.9s, novel: 16.3s, $F(1,56) = 25.83$, $p < .001$), as well as a marginal effect of Language (French: 15.5s, Spanish: 12.7s, $F(1,56) = 3.14$, $p = .082$), but no interactions. Despite differences in overall interest for the stimuli in this experiment, both French and Spanish infants show a robust novelty preference, demonstrating that they successfully discriminate stress patterns in the absence of segmental variation at 6 months. It should be noted that, similarly to what Skoruppa et al. (2009) found for 9-month-old infants, the drop-out rate is higher in this experiment than in Experiment 1, probably because this single-item experiment is rather monotonous.

To investigate possible developmental changes in basic stress processing, the French 6-month-olds' results in this experiment were compared to those of the 9-month-olds (see Figure 2, right) in Skoruppa et al. (2009), using a mixed-effect model as in Experiment 1 (full details in Table A2.3 in the Appendix). This analysis revealed a significant effect of Stress Pattern only (familiar: 13.7s vs. novel: 17.3s, $F(1,104) = 6.11$; $p = .015$). Thus, French infants' ability to discriminate stress patterns in the absence of segmental variation does not change between the ages of 6 and 9 months.

Finally, all 6-month-olds' data in the two experiments reported here were compared in a global ANOVA with the factors Experiment (1 vs. 2), Stress Pattern, Language, and Familiarization. This analysis showed significant effects of Experiment (Experiment 1: 17.1s, Experiment 2: 14.1s, $F(1,112)$, $p = .001$), Language (French: 17.5s, Spanish: 13.7s, $F(1.112) = 11.17$, $p = .009$), and Stress Pattern (familiar: 14.9s vs. novel: 16,3s, $F(1,112) = 4.19$, $p = .043$), as well as a significant interaction between Experiment and Stress Pattern ($F(1,112) = 18.12$, $p < .001$), reflecting the fact that infants discriminate between stress patterns in Experiment 2 (no variability), but not in Experiment 1 (with variability). Furthermore, there was a marginal interaction between Experiment, Familiarization, and Stress Pattern ($F(1,112) = 3.04$, $p = .084$). Crucially, there was no interaction between Language and Stress Pattern, showing that French and Spanish infants behave in the same way with respect to stress pattern discrimination with and without segmental variation at 6 months.

GENERAL DISCUSSION

We presented two experiments on stress pattern discrimination in 6-month-old French and Spanish infants using a familiarization-preference paradigm. In the first experiment, neither French nor Spanish 6-month-olds distinguished between initial and final stress in segmentally varied nonsense words. By contrast, in the second experiment, both French and Spanish 6-month-olds successfully discriminated stress patterns in multiple tokens of a single nonsense word, that

[3] Individual results can be found in the Appendix. Tables A2.1 and A2.2 show each infant's mean looking times for familiar and novel trials.

is, in a less demanding task in terms of phonological variability. The latter finding not only corroborates earlier research with French- and German-learning infants (Höhle et al., 2009) but also shows that 6-month-old infants' difficulty with segmentally varied stimuli in the first experiment does not lie in perceiving the acoustic cues for stress but rather in processing, representing, and/ or attending to the stress pattern of nonsense word sequences in the presence of concurrent segmental variation, on a more abstract, phonological level.

Taken together with earlier studies (Sansavini et al., 1997; Höhle et al., 2009; Skoruppa et al., 2009), our results show that infants can discriminate stress patterns in the absence of segmental variation throughout the first nine months of life, regardless of whether they learn a language with fixed or with variable stress. Specifically, we found that French infants' basic stress pattern perception in nonvaried stimuli does not change between the ages of 6 and 9 months. This contrasts with Mattock and Burnham (2006), who document a loss in sensitivity to nonnative tonal contrasts even in segmentally nonvaried stimuli between the ages of 6 and 9 months. While this difference might be due to the greater acoustic saliency of stress as opposed to tone, it would be interesting to examine whether an eventual decline in basic stress discrimination skills can be documented in learners of a fixed stress language later on, or in a more demanding task. Indeed, French adults have difficulty in perceiving stress patterns even in segmentally nonvaried stimuli in speeded discrimination (Dupoux et al., 1997) and sequence recall tasks (Dupoux et al., 2001); we might expect French-learning infants perform poorly even with segmentally nonvaried stimuli in a more difficult task than the one used here.

With respect to segmentally varied stimuli, we found no evidence that French infants encode their stress patterns at any tested age, at least in our paradigm. Furthermore, the Spanish 6-month-olds' failure in the first experiment clearly differs from the performance of the Spanish 9-month-olds' tested in Skoruppa et al. (2009), who showed a robust novelty preference. These results suggest that word stress processing becomes more flexible and robust between the ages of 6 and 9 months in Spanish infants, who are exposed to varying stress patterns in their native language. In fact, by the end of that period Spanish infants have developed word stress processing abilities that are sufficient to track stress patterns in running speech. At 9 months of age, their ability to process stress contrasts in stimuli containing variability is significantly better than that of infants learning French, a fixed stress language (Skoruppa et al., 2009), paralleling the cross-linguistic difference found in adults (Dupoux et al., 1997, 2001). Thus, in contrast to the majority of studies on the perception of nonnative segmental categories (Werker & Tees, 1984; Best & McRoberts, 2003; Best et al., 1995; Tsushima et al., 1994; Polka & Werker, 1994), as well as work on basic tone perception (Mattock & Burnham, 2006), infants' processing of native stress patterns *improves* during the second half of the first year of life. This seems to happen only if the input language has lexical stress variability. This is in line with studies showing an enhancement in the perception of difficult contrasts in the native language (Kuhl et al., 2006; Narayan et al., 2010; Sato et al., 2010), in more advanced, context-dependent tone perception (Shi, 2011), and, more generally, in the processing of variability (Houston & Jusczyk, 2000; Singh et al., 2004; Schmale et al., 2010; Dawson & Gerken, 2010). Since the strength of the stress cues was similar across both our experiments, it is possible that it is not the increase in variability per se, but the fact that segmental variability constitutes a competing dimension for infants to focus on that interferes with stress processing in our first experiment.

It would be interesting to further explore the role of variability in the processing of other aspects of suprasegmental structure. For instance, do Chinese-learning infants, whose perception of tonal contrasts in segmentally nonvaried stimuli remains stable between 6 and 9 months (Mattock & Burnham, 2006), improve with age when tested on segmentally varied stimuli, like they seem to do for tone stimuli in variable phonological contexts (Shi, 2011)?

Infants learning English, another language with variable stress, also successfully process stress pattern in the face of segmental variability by the end of the first year of life. Both 8- and 12-month-old American infants were tested with the segmentally varied stimuli used here and showed a robust novelty preference (Skoruppa et al., 2011). This proves that both English-learning and Spanish-learning infants possess sufficiently robust stress processing abilities that enable them to track stress patterns in fluent speech, although there may be fine-grained differences in the sensitivity to stress amongst learners, as demonstrated for adult speakers of these two languages (e.g., Soto-Faraco et al., 2001; Cooper et al., 2002). Such differences may not be picked up by our paradigm or may develop at a later age. Provided American and Spanish infants' abilities develop at roughly the same pace, this result enables us to further narrow down the age at which the developmental shift in stress processing occurs to between 6 and 8 months. It is worth noting that this shift coincides with another developmental milestone in early stress processing: American infants develop a trochaic bias (a preference for stress-initial words, the predominant stress pattern in English) between 6 and 9 months in the presence of segmental variability (Juscczyk et al., 1993; Turk et al., 1995). Likewise, Spanish infants prefer the most frequent native stress patterns in segmentally varied nonwords at 9 months (Pons & Bosch, 2010). These preferences depend on robust stress pattern processing in the presence of segmental variation; the fact that the latter ability significantly improves within the second half of the first year of life in infants learning variable stress languages may explain why the former develop at the same age, too.

However, this is not to say that infants do not learn anything about native stress patterns during the first 6 months of life. When only one pair of disyllabic stimuli differing in stress patterns is used, thus simplifying considerably the infant's task, German and French 4-month-olds already show cross-linguistic differences in their ERP discrimination response, suggesting that they have some sensitivity to the predominant stress pattern of their native language (Friedrici et al., 2007). Language-specific differences in stress pattern preferences for segmentally nonvaried stimuli have also been found in a head-turn procedure with German and French infants at 6 months (Höhle et al., 2009). Our study extends these results to more naturalistic stimuli containing segmental variation. Note, however, that we have only investigated stress processing for the most simple, disyllabic patterns (stress-initial vs. stress-final), and that the question of whether infants are able to track and generalize stress patterns in multisyllabic words remains to be explored.

Future work should also examine the underlying mechanisms by which infants learning variable stress languages develop these robust stress processing skills. Word segmentation abilities are still developing between 6 and 9 months of age (Jusczyk et al., 1999), and receptive vocabulary measures based on parental reports indicate that infants only understand a few dozen words during that period. For instance, both infants learning American English and infants learning Spanish only know around 15–50 words at 9 months (Fenson et al., 1994; López-Ornat et al., 2005). It is virtually impossible that these would include stress-based minimal pairs such as *discount* (N.) vs. *discount* (V.) in English or *saco* (N.) [ˈsako] - 'sack' vs. *sacó* (V.) [saˈko] - 'took out' in Spanish. Thus, it is highly unlikely that such young infants rely entirely on lexical learning mechanisms, although they could track the stress patterns of early-acquired and highly frequent words that often occur in isolation, such as their own name, which they know from the age of 4 months (Mandel, Jusczyk, & Pisoni, 1995). Furthermore, Peperkamp and Dupoux (2002) suggest that infants could analyze the distribution of stress at clause boundaries, to which English-learning infants are sensitive from 4 months on (Hirsh-Pasek et al., 1987; Seidl & Cristià, 2008). Given that in Spanish (and in English), words, and hence utterances, can be stressed on any of the last three syllables, this would allow infants to infer that lexical stress is contrastive. In order to evaluate the feasibility of such a distributional learning mechanism, research using naturalistic corpus data should test the robustness of the acoustic cues to lexical stress at utterance boundaries, where interactions with other prosodic phenomena such as focus placement and phrase-final lengthening are to be expected.

ACKNOWLEDGMENTS

This work was funded by grants from the French Agence Nationale de la Recherche (ANR-2010-BLAN-1901), the Fondation de France, and the Spanish Ministerio de Ciencia e Innovación (PSI2008-01253, PSI2010-20294 and PSI2011-25376). We are grateful to Rita Alves-Limissuri, Sylvie Margules, Jorgina Solé and Maria Teixidó for help in recruiting and running participants.

REFERENCES

Best, C. T., & McRoberts, G. W. (2003). Infant perception of nonnative consonant contrasts that adults assimilate in different ways. *Language and Speech*, *46*, 183–216.

Best, C. T., McRoberts, G. W., LaFleur, R., & Silver-Isenstadt, J. (1995). Divergent developmental patterns for infants' perception of two nonnative consonant contrasts. *Infant Behavior & Development*, *18*, 339–350.

Bosch, L., & Sebastián-Gallés, N. (2001). Evidence of early language discrimination abilities in infants from bilingual environments. *Infancy*, *2*, 29–49.

Cooper, N., Cutler, A., & Wales, R. (2002). Constraints of lexical stress on lexical access in English: Evidence from native and nonnative listeners. *Language and Speech*, *45*, 207–228.

Curtin, S. (2009). Twelve-month-olds learn novel word–object pairings differing only in stress pattern. *Journal of Child Language*, *36*, 1157–1165.

Cutler, A. (1986). Forbear is a homophone: Lexical prosody does not constrain lexical access. *Language and Speech*, *29*, 201–220.

Cutler, A., & Norris, D. (1988). The role of strong syllables in segmentation for lexical access. *Journal of Experimental Psychology: Human Perception and Performance*, *14*, 113–121.

Dawson, C., & Gerken, L. A. (2010). Before domain specificity: When "simple" matters more. Presentation at the International Conference on Infant Studies, Baltimore, MD, March 11–14.

Dupoux, E., Pallier, C., Sebastián-Gallés, N., & Mehler, J. (1997). A destressing "deafness" in French? *Journal of Memory and Language*, *36*, 406–421.

Dupoux, E., Peperkamp, S., & Sebastián-Gallés, N. (2001). A robust method to study stress "deafness." *Journal of the Acoustical Society of America*, *110*, 1606–1618.

Fenson, L., Dale, P. S., Reznick, J. S., Bates, E., Thal, D. J., & Pethick, S. J. (1994). Variability in early communicative development. *Monographs of the Society for Research in Child Development*, *59*.

Friederici, A. D., Friedrich, M., & Christophe, A. (2007). Brain responses in 4-month-old infants are already language specific. *Current Biology*, *17*, 1208–1211.

Fry, D. B. (1958). Experiments in the perception of stress. *Language and Speech*, *1*, 126–152.

Hirsh-Pasek, K., Kemler-Nelson, D. G., Jusczyk, P. W., Wright Cassidy, K., Druss, B., & Kennedy, L. (1987). Clauses are perceptual units for young infants. *Cognition*, *26*, 269–286.

Höhle, B., Bijeljac-Babic, R., Herold, B., Weissenborn, J., & Nazzi, T. (2009). Language specific prosodic preferences during the first half year of life: Evidence from German and French infants. *Infant Behavior and Development*, *32*, 262–274.

Houston, D. M., & Jusczyk, P. W. (2000). The role of talker-specific information in word segmentation by infants. *Journal of Experimental Psychology: Human Perception and Performance*, *26*, 1570–1582.

Jusczyk, P. W., Cutler, A., & Redanz, N. (1993). Infants' preference for the predominant stress patterns of English words. *Child Development*, *64*, 675–687.

Jusczyk, P. W., Houston, D. M., & Newsome, M. (1999). The beginnings of word segmentation in English-learning infants. *Cognitive Psychology*, *39*(3–4), 159–207.

Kuhl, P., Stevens, E., Hayashi, A., Deguchi, T., Kiritani, S., & Iverson, P. (2006). Infants show a facilitation effect for native language phonetic perception between 6 and 12 months. *Developmental Science*, *9*, F13–21.

López-Ornat, S., Gallego, C., Gallo, P., Karousou, A., Mariscal, S., & Martínez, M. (2005). *Inventario de desarrollo comunicativo MacArthur (adaptacion española)*. Madrid, Spain: TEA Ediciones.

Maas, C. J. M., & Hox, J. J. (2004). Robustness issues in multilevel regression analysis. *Statistica Neerlandica*, *58*, 127–137.

Mandel, D. R., Jusczyk, P. W., & Pisoni, D. B. (1995). Infants' recognition of the sound patterns of their own names. *Psychological Science*, *6*, 314–317.

Mattock, K., & Burnham, D. (2006). Chinese and English infants' tone perception: Evidence for perceptual reorganization. *Infancy*, *10*, 241–265.

Narayan, C. R., Werker, J. F., & Beddor, P. S. (2010). The interaction between acoustic salience and language experience in developmental speech perception: Evidence from nasal place discrimination. *Developmental Science*, *13*, 407–420.

Peperkamp, S., & Dupoux, E. (2002). A typological study of stress "deafness." In C. Gussenhoven & N. Warner (Eds.), *Laboratory phonology VII* (pp. 203–240). Berlin, Germany: Mouton de Gruyter.

Polka, L., & Werker, J. (1994). Developmental changes in perception of nonnative vowel contrasts. *Journal of Experimental Psychology: Human Perception and Performance*, *20*, 421–435.

Pons, F., and Bosch, L. (2010). Stress pattern preference in Spanish-learning infants: The role of syllable weight. *Infancy*, *15*, 223–245.

Rost, G. C., & McMurray, B. (2009). Speaker variability augments phonological processing in early word learning. *Developmental Science*, *12*(2), 339–349.

Rost, G. C., & McMurray, B. (2010). Finding the signal by adding noise: The role of noncontrastive phonetic variability in early word learning. *Infancy*, *15*(6), 608–635.

Sansavini, A., Bertoncini, J., & Giovanelli, G. (1997). Newborns discriminate the rhythm of multisyllabic stressed words. *Developmental Psychology*, *33*, 3–11.

Sato, Y., Sogabe, Y., & Mazuka, R. (2010). Discrimination of phonemic vowel length by Japanese infants. *Developmental Psychology*, *46*, 106–119.

Schmale, R., Cristià, A., Seidl, A., & Johnson, E. (2010). Developmental changes in infants' ability to cope with dialect variation in word recognition. *Infancy, 15*, 650–662.

Seidl, A., & Cristià, A. (2008). Developmental changes in the weighting of prosodic cues. *Developmental Science*, *11*, 596–606.

Shi, R. (2010). Contextual variability and infants' perception of tonal categories. *Chinese Journal of Phonetics*, *2*, 1–9.

Singh, L., Morgan, J. L., & White, K. S. (2004). Preference and processing: The role of speech affect in early spoken word recognition. *Journal of Memory and Language*, *51*, 173–189.

Skoruppa, K., Cristià, A., Peperkamp, S., & Seidl, A. (2011). English-learning infants' perception of word stress patterns. *Journal of the Acoustical Society of America*, *130*, EL50–55.

Skoruppa, K., Pons, F., Christophe, A., Bosch, L., Dupoux, E., Sebastián-Gallés, N., . . . Peperkamp, S. (2009). Language-specific stress perception by 9-month-old French and Spanish infants. *Developmental Science*, *12*, 914–919.

Small, L. H., Simon, S. D., & Goldberg, J. S. (1988). Lexical stress and lexical access – homographs versus nonhomographs. *Perception and Psychophysics*, *44*, 272–280.

Soto-Faraco, S., Sebastian-Galles, N., & Cutler, A. (2001). Segmental and suprasegmental mismatch in lexical access. *Journal of Memory and Language*, *45*, 412–432.

Tsushima, T., Takizawa, O., Sasaki, M., Shiraki, S., Nishi, K., Kohno, M., . . . Best, C. (1994). Discrimination of English /r-l/ and /w-y/ by Japanese infants at 6-12 months: Language-specific developmental changes in speech perception abilities. *1994 International Conference on Spoken Language Processing* (pp. 1695–1698). Yokohama, Japan.

Turk, A. E., Jusczyk, P. W., & Gerken, L. (1995). Do English-learning infants use syllable weight to determine stress? *Language and Speech*, *38*, 143–158.
Vroomen, J., Tuomainen, J., & de Gelder, B. (1998). The roles of word stress and vowel harmony in speech segmentation. *Journal of Memory and Language*, *38*, 133–149.
Werker, J. F., & Tees, R. C. (1984). Cross-language speech perception: Evidence for perceptual reorganization during the first year of life. *Infant Behavior and Development*, *7*, 49–63.

APPENDIX

TABLE A1.1
French infants' individual looking times in seconds in Experiment 1, by familiarization and stress pattern

	stress-final			*stress-initial*	
participant	*familiar*	*novel*	*participant*	*familiar*	*novel*
1	14.52	13.46	16	27.76	10.50
2	25.94	28.32	17	21.06	28.34
3	28.78	29.78	18	27.48	29.10
4	20.44	10.64	19	18.42	17.78
5	23.32	16.04	20	17.02	24.40
6	6.26	21.04	21	27.32	12.12
7	20.40	19.08	22	17.16	5.52
8	16.10	18.36	23	16.66	23.54
9	26.18	21.10	24	28.78	26.06
10	3.16	8.36	25	25.90	14.98
11	15.32	11.70	26	4.24	16.38
12	25.02	21.60	27	15.82	29.96
13	29.64	21.32	28	28.24	28.74
14	29.80	10.90	29	22.84	17.32
15	15.55	25.65	30	7.36	5.14

TABLE A1.2
Spanish infants' individual looking times in seconds in Experiment 1, by familiarization and stress pattern

	stress-final			*stress-initial*	
participant	*familiar*	*novel*	*participant*	*familiar*	*novel*
1	21.79	26.97	16	9.87	19.41
2	21.29	10.92	17	13.27	20.68
3	6.92	7.90	18	26.52	21.77
4	4.47	7.63	19	24.01	7.09
5	6.30	7.56	20	19.14	26.84
6	13.98	8.12	21	29.35	29.23
7	14.16	15.34	22	19.52	27.62
8	11.64	11.51	23	5.89	12.73
9	10.17	11.81	24	27.99	26.62
10	28.89	5.89	25	16.37	7.35
11	14.36	10.00	26	13.14	5.41
12	14.61	5.99	27	4.12	6.71
13	22.05	5.79	28	17.79	26.21
14	16.64	11.03	29	3.32	5.74
15	8.20	5.21	30	22.01	20.27

TABLE A1.3
Fixed-effect part of the GLMM for 6- and 9-month-old French and Spanish infants in Experiment 1

Source	*F*	*df1*	*df2*	*p*
Corrected Model	5.453	7	178	.000
Language	4.622	1	106	.034
Stress Pattern	0.138	1	208	.711
Age	17.120	1	106	.000
Language * Age	4.443	1	106	.037
Language * Stress Pattern	1.000	1	208	.319
Age * Stress Pattern	6.726	1	208	.010
Language * Age * Stress Pattern	1.740	1	208	.189

TABLE A1.4
Fixed-effect part of the GLMM for 6- and 9-month-old French infants in Experiment 1

Source	*F*	*df1*	*df2*	*p*
Corrected Model	7.034	3	104	.000
Stress Pattern	0.198	1	104	.658
Age	20.380	1	57	.000
Age * Stress Pattern	0.812	1	104	.370

TABLE A1.5
Fixed-effect part of the GLMM for 6- and 9-month-old Spanish infants in Experiment 1

Source	*F*	*df1*	*df2*	*p*
Corrected Model	3.931	3	104	.011
Stress Pattern	0.940	1	104	.335
Age	1.975	1	50	.166
Age * Stress Pattern	7.653	1	104	.007

TABLE A2.1
French infants' individual looking times in seconds in Experiment 2, by familiarization and stress pattern

	stress-final			*stress-initial*	
participant	*familiar*	*novel*	*participant*	*familiar*	*novel*
1	3.50	14.40	16	27.02	10.86
2	28.52	30.24	17	8.14	4.16
3	11.94	8.58	18	14.24	14.00
4	7.88	13.76	19	15.02	25.76
5	9.84	7.70	20	8.92	11.34
6	9.28	24.48	21	11.24	4.92
7	9.98	20.62	22	17.10	19.66
8	11.98	17.46	23	7.00	21.02
9	25.22	15.90	24	5.32	17.02
10	12.20	21.50	25	19.36	29.54
11	26.24	26.00	26	16.66	20.40
12	21.32	27.18	27	17.44	18.18
13	4.44	8.60	28	12.10	10.06
14	3.12	2.48	29	10.50	21.20
15	27.58	27.72	30	15.58	14.78

TABLE A2.2
Spanish infants' individual looking times in seconds in Experiment 2, by familiarization and stress pattern

	stress-final			*stress-initial*	
participant	*familiar*	*novel*	*participant*	*familiar*	*novel*
1	10.16	18.18	16	14.76	21.04
2	20.64	17.34	17	9.48	20.30
3	4.50	12.00	18	3.82	6.70
4	15.32	16.18	19	9.50	14.00
5	5.64	25.20	20	5.28	20.40
6	3.30	19.80	21	9.74	9.38
7	6.90	7.74	22	9.42	12.02
8	6.22	9.96	23	15.26	22.18
9	9.78	20.22	24	16.82	15.58
10	6.92	22.52	25	10.58	14.16
11	6.26	20.84	26	8.48	11.76
12	8.56	11.30	27	7.40	10.26
13	4.34	13.38	28	22.88	23.64
14	7.60	13.30	29	4.00	5.86
15	27.44	24.16	30	5.82	8.10

TABLE A2.3
Fixed-effect part of GLMM for 6- and 9-month-old French infants in Experiment 2

Source	*F*	*df1*	*df2*	*p*
Corrected Model	2.042	3	104	.113
Age	0.002	1	104	.961
Stress Pattern	6.113	1	50	.015
Age * Stress Pattern	0.145	1	104	.704