SENSITIVITY TO NON-ADJACENT PHONOLOGICAL DEPENDENCIES IN 10-MONTH-OLD INFANTS

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ABSTRACT

Languages instantiate many different kinds of dependencies, holding between adjacent or non-adjacent elements. In the domain of phonotactics, while sensitivity to adjacent dependencies emerges between 6 and 10 months, it is unknown when sensitivity to nonadjacent dependencies emerges. The present study tests a perceptual equivalent of the Labial-Coronal (LC) bias, a dependency involving two non-adjacent consonants. We show that 10-, but not 7-month-old, French-learning infants have a preference for LC words over CL (Coronal-Labial) words that cannot be explained by adjacent dependencies or by a preference for more frequent coronal consonants. The present study thus brings the first piece of evidence that infants are sensitive to non-adjacent dependencies at the phonotactic level by 10 months.

Keywords: infancy, speech perception, phonological acquisition, phonotactics

1. INTRODUCTION

Many studies have shown how infants' initial language-general abilities change into abilities that are attuned to the language they are acquiring. Within the phonological domain, these studies have established that infants start learning the prosodic [1, 4]) and phonetic [6, 10] properties of their native language before their first birthday. However, infants have to acquire different sorts of native phonological properties, as a consequence of the fact that regularities in their native language occur at different levels of organization.

Several levels of phonological organization can be distinguished. First, languages instantiate frequency regularities, some sounds being more frequent than others, as illustrated by the fact that crosslinguistically coronal consonants are more frequent than dorsal consonants. Second, positional regularities, which refer to the fact that some sounds are more frequent in some positions than in others, can also be observed, such as the predominance of Coronal-initial over Labial-initial words in French. Third, adjacent regularities refer to dependencies between sounds that are adjacent in the speech signal, such as the fact that in a given language, some consonant clusters are allowed but not others (for example, in English, the sound /θ/ at the beginning of a syllable can be followed by /r/ but not by /m/).

Fourth, languages present many types of non-adjacent phonological dependencies. For instance, many languages exhibit vowel harmony (e.g., Turkish that presents front/back harmony). Moreover, in Semitic languages, families of words correspond to consonantal roots, and variations in vowel identity indicate lexical class, number, gender… These phenomena break the adjacency of the lexical root information.

Previous studies have shown that infants start distinguishing between legal/frequent and illegal/ infrequent sequences of adjacent phonemes in their native language between 6 and 10 months of age [3, 5] as attested by listening preferences for the legal or more frequent structures. However, all of these findings can be accounted for by sensitivity to frequency/positional/adjacent properties.

At present, only one previous study has explored whether infants might learn non-adjacent dependencies [8]. In that perception study, the dependencies investigated involved the distinction between Labial-Coronal (LC) words (that is, words starting with a labial consonant followed by a coronal consonant) and Coronal-Labial (CL) words (the opposite pattern), a distinction considered as a non-adjacent relation between two consonants separated by a vowel. In many languages, including French, the language of the infants tested, LC words are more frequent than CL words (Table 1). The LC bias had previously been found in early word production, and had been interpreted in terms of production constraints according to which producing an LC sequence required less and easier movements than producing a CL sequence [2, 7]. In the perception study by [8], infants started preferring the LC words between 6 and 10 months.

These results were interpreted as evidence that, at a perceptual (rather than production) level, infants have become sensitive to these non-adjacent dependencies by 10 months.

Table 1: Frequency of LC and CL French words according to Lexique 3 [9].

	All words	CVC words only
Lab-Cor	71,822	6,808
Cor-Lab	42,772	1,179

However, two features of that study prevent us from making strong conclusions about the acquisition of non-adjacent dependencies. First, because bisyllabic stimuli were used, the LC bias could have resulted from the acquisition of dependencies between the two adjacent syllables. Second, a close analysis of the stimuli also revealed differences in terms of adjacent dependencies which were higher for the LC words. Given these facts, the present study explores the emergence of an LC bias using monosyllabic CVC words and controlling for adjacent frequencies.

2. EXPERIMENT 1: LC AND CL STIMULI

2.1. Participants

Sixteen healthy full-term French-learning 7-month-olds and 16 10-month-olds were tested.

2.2. Stimuli

The auditory stimuli were 24 French monosyllabic words with a CVC structure recorded by a female native speaker, and arranged in two speech files: a list of 12 words with an LC structure and a list of 12 words with a CL structure. Adjacent frequencies were matched across lists using the adult database Lexique 3 [9].

2.3. Procedure

We used the Headturn Preference Procedure, as done in [8]. During the testing session, the infant is seated on the lap of a caregiver in the center of a test booth. Inside the booth, three lamps are fixated: a central green one, and a red one on each side. Directly above the green lamp on the center wall is a video-camera. Two hidden loudspeakers are mounted at the level of the red lamps.

Each experimental trial is started by the blinking of the green center lamp. When the infant orients to the green lamp, this lamp goes out and one of the red lamps starts to blink. When the infant turns her head towards the lamp, the stimulus is presented from the loudspeaker on the same side. The trial ends when the infant turns away for more than 2 s, or when the end of the speech file is reached. If the child turns away for less than 2 s, the presentation of the speech file is continued but the time spent looking away is not included in the total orientation time. The experiment started with 2 warm-up trials in which music was presented. The remaining 8 trials (4 LC and 4 CL trials) were presented in random order.

We also collected questionnaires to estimate the babbling level of each infant.

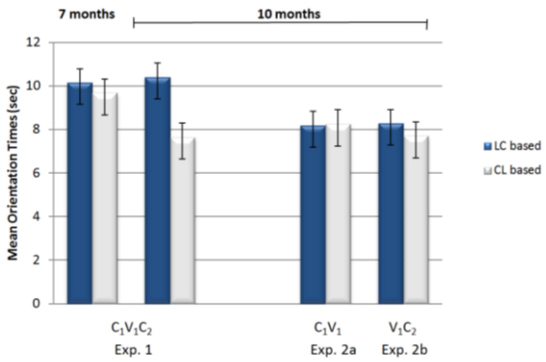
2.4. Results and discussion

Mean orientation times to the LC and CL lists were calculated at both ages (Figure 1, left panel). An ANOVA with the factors of age (7 vs. 10 months) and lexical structure (LC vs. CL) revealed a significant effect of lexical structure, $F(1, 30) = 7.19$, $p = .01$, infants having longer orientation times to LC than CL words. While the effect of age was not significant, $F(1, 30) = 1.55$, $p = .22$, the age x lexical structure interaction approached significance, $F(1, 30) = 3.5$, $p = .06$, indicating that the effect of lexical structure changed with age. Planned comparisons indicated that the lexical structure effect was not significant at 7 months, $F(1, 30) < 1$, but was significant at 10 months, $F(1, 30) = 10.41$, $p < .001$.

The results of the babbling questionnaire indicated that no infant produced babbling sequences with varied consonants, hence that none of them produced LC or CL structures.

The present results extend to monosyllabic words the emergence of a perceptual Labial-Coronal bias by 10 months of age found in [8]. Moreover, this emergence appears before LC and CL structures start being produced, hence appear not to be linked to infants' own productions. Since the adjacent frequencies within the stimuli had been controlled, these findings are compatible with the notion that 10-month-olds have become sensitive to non-adjacent phonotactic dependencies in the native language. However, because the adjacent frequency controls had been done on an adult database which might not fully correspond to the infants' input, we decided to run two control experiments at 10 months, presenting infants with stimuli consisting of either the first two (Exp. 2a) or the last two (Exp. 2b) phonemes of the original stimuli. If adjacent frequencies are indeed balanced with respect to the infants' input, then no preferences should be observed in both control experiments. Such results would also exclude alternative interpretations in terms of a preference for Labial-initial words or Coronal-final words.

Figure 1: Mean orientation times (and SD) to LC vs. CL stimuli at 7 and 10 months in Exp. 1 (left panel), and to L- vs. C-initial items in Exp. 2a and L- vs. C-final items in Exp. 2b at 10 months (right panel).



3. EXPERIMENT 2A/B: ADJACENT CONTROLS

3.1. Participants

Two groups of 16 healthy full-term French-learning 10-month-olds were tested.

3.2. Stimuli

The auditory stimuli were derived from those of Exp. 1. In Exp. 2a, the final consonants were removed in order to obtain L- versus C-initial CV sequences; in Exp. 2b, the initial consonants were removed in order to obtain C- versus L-final VC sequences. Due to a couple of repetitions, the 4 final lists contained 10 sequences each. The stimuli were recorded by the same speaker as in Exp. 1.

3.3. Procedure

The procedure was identical to Exp. 1.

3.4. Results and discussion

Mean orientation times to the L- and C-initial lists of Exp. 2a, and those to the C- and L-final lists of Exp. 2b were calculated (Figure 1, right panel). A 2-way ANOVA with the factors of Experiment (Exp. 2a vs. 2b) and lexical structure (LC-based vs. CL-based) was conducted. Both main effects were not significant (both $F(1, 30) < 1$). Additionally, the interaction between experiment and lexical structure was not significant, $F(1, 30) < 1$. Planned comparisons showed that the lexical structure effect was not significant both in Exp. 2a, $F(1, 30) < 1$, and in Exp. 2b, $F(1, 30) = 1.57$, $p = .21$.

The absence of preference in the present experiments suggests that the adjacent frequency controls based on the adult Lexique 3 database were appropriate for infant testing, or that 10-month-olds are not sensitive/attentive to adjacent properties in this kind of experiments.

Moreover, note that while analyses in Lexique 3 showed that C-initial and C-final words are more frequent than words starting or finishing with a labial consonant (Table 2), the results of the present control experiments did not reveal a preference for stimuli with Coronal consonants over stimuli with Labial consonants (no C-initial bias in Exp. 2a; no C-final bias in Exp. 2b). The fact that these frequency differences were not mirrored in our data suggests that at 10 months, overall/positional phoneme frequencies do not influence infants' listening preferences.

Table 2: Cumulative frequency of L- versus C-initial, and L- versus C-final words according to the French adult database Lexique 3.

	Word Onset		Word Coda	
	Monosyllables	All Words	Monosyllables	All Words
Labial	37,140	187,137	1,745	19,272
Coronal	165,813	306,040	44,359	125,184

Lastly, results of the babbling questionnaires showed that as in Exp. 1, none of the infants were producing LC and CL structures.

4. GENERAL DISCUSSION

The goal of the present study was to explore the early acquisition of nonadjacent phonological properties of the native language. Accordingly, we investigated when in development French-learning infants develop a preference for CVC items with a labial-coronal structure over CVC items with a coronal-labial structure, the labial-coronal structure being comparatively more frequent in French (Table 1). The results of Exp. 1 showed that this bias emerges between 7 and 10 months of age, a finding predicted by nonadjacent acquisition.

This non-adjacent interpretation is reinforced by two key features of our design. First, the stimuli were constructed so that frequencies of adjacent dependencies were matched between the LC and CL lists, using the adult database Lexique 3. Second, because these controls were made on an adult database (the only one available to perform such controls), and because we could not be fully certain that such frequency controls would be appropriate for infant studies, sensitivity to possible differences in adjacent frequencies from an infant perspective were directly tested by presenting infants with only the first or last two phonemes of the original stimuli (Exp. 2a-b). These stimuli have the same adjacent properties of the original stimuli, but lack the non-adjacent dependency between the consonants. The absence of preferences in Exp. 2a-b establishes that 10-month-olds in Exp. 1 were not responding to adjacent properties, but to non-adjacent properties, namely the predominance of LC words over CL words in the French lexicon.

Therefore, the present study is the first to establish that infants become sensitive to non-adjacent dependencies at the phonological (phonotactic) level very early in development, that is, between 7 and 10 months of age. This is the same time period during which infants have been found to become sensitive to native phonotactic properties in previous studies [3, 5, 8], suggesting no delay in the acquisition of non-adjacent phonological dependencies compared to adjacent ones in the phonological domain.

The present findings also have implications for our understanding of the nature of the labial-coronal bias. Classically, the bias has been interpreted as the result of production constraints [2, 7]. In contrast, a perceptual interpretation was offered in a more recent study where the LC effect was observed in perception at 10 months [8]. This perceptual interpretation is reinforced by the results of Exp. 1 that extend the preference effect found at 10 months from bisyllabic to monosyllabic items, using more controlled stimuli. This interpretation is further confirmed by the results of the babbling questionnaire establishing that none of the 10-month-olds tested in the present study produced either LC or CL structures. Therefore, we propose that the labial-coronal bias involves both perceptual and production factors, since the labial-coronal bias found at 10 months is likely to reflect the perceptual acquisition of input regularities possibly reflecting articulatory constraints. One way to further explore the relationship between these perceptual and production effects would be to test infants growing up learning a language that does not show a labial-coronal advantage in the input, and determine whether or not this affects the emergence of a perceptual bias around 10 months, and a production bias in the second year of life. Japanese would constitute such a language.

In conclusion, the present study provides the first evidence that infants become sensitive to non-adjacent phonotactic dependencies in their native language between 7 and 10 months of age.

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