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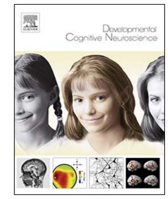

A novel form of perceptual attunement: Context-dependent perception of a native contrast in 14-month-old infants

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ABSTRACT

By the end of their first year of life, infants have become experts in discriminating the sounds of their native language, while they have lost the ability to discriminate non-native contrasts. This type of phonetic learning is referred to as perceptual attunement. In the present study, we investigated the emergence of a context-dependent form of perceptual attunement in infancy. Indeed, some native contrasts are not discriminated in certain phonological contexts by adults, due to the presence of a language-specific process that neutralizes the contrasts in those contexts. We used a mismatch design and recorded high-density Electroencephalography (EEG) in French-learning 14-month-olds. Our results show that similarly to French adults, infants fail to discriminate a native voicing contrast (e.g., [f] vs. [v]) when it occurs in a specific phonological context (e.g. [ofbe] vs. [ovbe], no mismatch response), while they successfully detected it in other phonological contexts (e.g., [ofne] vs. [ovne], mismatch response). The present results demonstrate for the first time that by the age of 14 months, infants' phonetic learning does not only rely on the processing of individual sounds, but also takes into account in a language-specific manner the phonological contexts in which these sounds occur.

1. Introduction

Speech is an inherently variable signal: tokens of identical phonemes and words are acoustically distinct. When acquiring their native language, infants have thus to detect the equivalence of these different tokens in spite of their variability. For instance, the acoustic properties of consonants differ as a function of the following vowel. After only a few months of life, infants normalize this acoustic variation (Bertoncini et al., 1988; Hochmann and Papeo, 2014; Mersad and Dehaene-Lambertz, 2016). Infants must also detect which aspects of phonetic variation in the speech signal are meaningful, i.e. reflect distinctions among the phonemes and hence words of their native language. Numerous behavioral studies report that by the end of the first year of life, infants have learned to interpret which phonetic distinctions are relevant (or not) to recognize the phonemes of their native language (e.g., Kuhl et al., 1992; Polka et al., 1994; Werker and Tees, 1984). More recently, electrophysiological measures have confirmed these findings (Bosseler et al., 2013; Conboy and Kuhl, 2011; Peña et al., 2012; Rivera-Gaxiola et al., 2007a, 2005a,b). For instance, Peña et al. (2012) collected electro-encephalographic (EEG) measures in 9- and 12-month-old Spanish-learning infants using a mismatch paradigm. They computed infants' auditory mismatch response (MMR), an ERP component that reflects the automatic detection of perceptual change in both adults (Näätänen et al., 1997, 2012) and infants (Dehaene-Lambertz and Baillet, 1998; Dehaene-Lambertz and Dehaene, 1994). In each trial, infants listened to a series of three identical syllables ([ɖa]) that were followed by a fourth syllable that was either identical or differed from them in the first consonant. Crucially, the deviant consonant always differed on the same phonetic feature (i.e., place of articulation) but could be either native (i.e., [ba]) or non-native (i.e., [ɖa], with [ɖ] a retroflex consonant that does not occur in Spanish). The authors observed that at 9 months, infants showed a MMR in response to both the native and the non-native deviant consonants; hence, they detected the phonetic change in place of articulation from [ɖa] to both

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native [ba] and non-native [ɖa]. By contrast, 12-month-olds showed a MMR in response to the change to native [ba], but failed to detect the phonetic change to non-native [ɖa].

Thus, by the age of 12 months, infants have lost the ability to discriminate non-native phonetic contrasts. This type of phonetic learning is often referred to as *perceptual attunement* (or *perceptual narrowing*). It should be noted that perceptual attunement likewise occurs in the case of *native* phonetic contrasts that are not used to distinguish word meaning. For instance, in English, the consonant [t] is usually aspirated when it occurs before a vowel (as in *top* [tʰɔp]), but it is unaspirated if preceded by [s], (as in *stop* [stɔp]). Acoustically, this unaspirated [t] is very similar to [d], which never occurs preceded by [s], and native English adults have difficulty discriminating the contrast between unaspirated [t] and [d] despite the fact that they both occur in their language. Importantly, English-learning infants discriminate the contrast at 6–8 months of age, but fail to do so by the time they are 10–months of age, thus showing perceptual attunement (Pegg and Werker, 1997). In a similar vein, English-learning infants lose their sensitivity to the contrast between oral and nasal vowels between the ages of 4 and 11 months (Seidl et al., 2009). While both types of vowels occur in their language, the contrast between them is never used to distinguish meaning: nasal vowels are phonetic variants of oral vowels, occurring before nasal consonants (cf. *beet* and *bean*, whose vowels only differ in nasality).

In this article we focus on yet another type of perceptual attunement, which has hitherto not been investigated. Specifically, depending upon the phonological context in which they appear, even native contrasts that *are* used to distinguish word meaning can be difficult to discriminate (Mitterer and Blomert, 2003; Sun et al., 2015). For instance, Sun et al. (2015) collected EEG measures in a mismatch paradigm and showed that French adults do not detect a change from [ofbe] to [ovbe] (i.e., they fail to show a MMR), despite the fact that the distinction between [f] and [v], a voicing[2] distinction, is phonemic in their language and hence used to distinguish meaning (e.g., *greffe* [gʁɛf] 'graft' – *grève* [gʁɛv] 'strike'); by contrast, they correctly detect a change from [ofne] to [ovne], as evidenced by the presence of a MMR. This result can be explained by the fact that in French, native voicing contrasts – such as the one between [f] and [v] – can be neutralized in certain phonological contexts. Specifically, in speech production, voiceless consonants can become voiced when followed by certain voiced consonants, a process called *voicing assimilation.*[3] For instance, the voiceless [f] in *oeuf* [œf] 'egg' is typically produced as its voiced counterpart [v] in *oeuf blanc* [œvblɑ̃] 'white egg', where it is followed by [b]. This process does not apply, however, in *oeuf noir* [œfnwaʁ] 'black egg', where it is followed by [n]. Specifically, French voicing assimilation applies before voiced obstruents (such as [b]) but not in other contexts (such as before [n]). The findings by Sun et al. (2015), then, show that this process affects speech perception: when presented with consonants in an assimilation context (i.e., followed by a voiced obstruent), French adults fail to detect a change in voicing. In other words, the capacity to discriminate a native contrast depends upon the phonological context in which the contrast occurs.

For phonetic learning, this raises the question of whether infants' perceptual attunement is likewise context-dependent, taking into account language-specific phonological processes and the contexts in which they apply. Nine-month-old infants are sensitive to phonological context: they have acquired constraints upon the sequencing of phonemes within syllables and words in their language (i.e., phonotactics), and prefer to listen to phoneme sequences that are phonotactically legal or frequent as opposed to illegal or infrequent (Friederici and Wessels, 1993; Jusczyk et al., 1993; Jusczyk and Luce, 1994). Moreover, 14-month-old infants show some evidence of context-sensitive perceptual attunement: Japanese infants of this age perceive an illusory vowel within consonant clusters that are illegal in their language (Mazuka et al., 2011), similarly to Japanese adults (Dehaene-Lambertz et al., 2000; Dupoux et al., 1999). However, whether and how language-specific phonological processes (like French voicing assimilation) influence infants' capacity to discriminate native phoneme contrasts in the context of these processes has not been investigated.

In the present study, we thus tested whether French 14-month-olds, who have already lost the ability to distinguish non-native contrasts,[4] are also insensitive to the native voicing contrast when it occurs in an assimilation context. We recorded high-density EEG, using a mismatch trial design as in Peña et al. (2012). We analyzed the presence or absence of a MMR in response to a voicing change in two types of context, one that allows and one that does not allow for voicing assimilation. The MMR is particularly suited to study native phoneme discrimination, given its sensitivity to the linguistic relevance of the phonetic change in the participant's native language (Dehaene-Lambertz and Baillet, 1998; Näätänen et al., 1997). If 14-month-olds have already developed sensitivity to the native process of voicing assimilation, they should – like French adults – exhibit a MMR in response to a voicing change only in contexts that cannot trigger voicing assimilation in French. Alternatively, if they have not yet developed this sensitivity, they should exhibit a MMR to a voicing change regardless of context.

2. Material and methods

2.1. Participants

Forty-three healthy infants (23 females; mean age: 427 days, range: 396–441 days) raised in a monolingual French-speaking environment participated in the study. All infants were born full-term (37–42 weeks gestation) with normal birthweight (> 2500 g). All parents gave informed consent before the study. According to parental report, infants had normal vision and audition and had no exposure to other languages. Forty additional infants were excluded from the analyses because of an insufficient number of trials (N = 27), parental interference (N = 2), or because they presented less than 13 artifact-free EEG trials per condition (N = 11). We received 29 others infants who did not provide any data because they refused to wear the net.

2.2. Design and stimuli

The stimuli were a subset of the ones used by Sun et al. (2015); they all had a vowel-consonant-consonant-vowel structure ($V_1C_1C_2V_2$). Given infants' limited attention span, we used two out of the eight original item pairs, i.e. [ofbe]-[ofne] and [ikdo]-[ikmo]. Each of the precursor stimuli was spoken by four female speakers, while the test stimuli was spoken by a male speaker (we used one token per speaker); the use of multiple speakers promotes the detection of phonological rather than purely acoustical changes (Dehaene-Lambertz, 2000; Eulitz and Lahiri, 2004). All $V_1C_1C_2V_2$ tokens was created by means of cross-splicing of entirely voiceless C_1C_2 consonant clusters with entirely voiced ones. Thus, in all stimuli (both precursor and test stimuli), C_1 was always completely voiceless or voiced across all the conditions. For instance, [ofbe] was created by combining [of]- from [ofpe] and –[be]

[2] Voicing is the phonetic feature that refers to the vibration of the vocal cords during the production of a given speech sound. Sounds that are produced with vibration of the vocal cords are called voiced, and those without vibration are called voiceless.

[3] Similarly, certain voiced consonants can become voiceless when followed by a voiceless consonant. In this article, however, we are only concerned with the change from voiceless to voiced.

[4] To our knowledge, there is no ERP study investigating perceptual attunement for phoneme categories in French-learning infants, but given that it has been documented at 12 months of age for infants learning a number of languages, including English, Spanish, and Japanese, we have every reason to assume that French 14-month-olds have likewise acquired their native phoneme categories.