



Original Articles

Lexical stress constrains English-learning infants' segmentation in a non-native language

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ABSTRACT

Infants' ability to segment words in fluent speech is affected by their language experience. In this study we investigated the conditions under which infants can segment words in a non-native language. Using the Head-turn Preference Procedure, we found that monolingual English-learning 8-month-olds can segment bisyllabic words in Spanish (trochees and iambs) but not French (iambs). Our results are incompatible with accounts that rely on distributional learning, language rhythm similarity, or target word prosodic shape alone. Instead, we show that monolingual English-learning infants are able to segment words in a non-native language as long as words have stress, as is the case in English. More specifically, we show that even in a rhythmically different non-native language, English-learning infants can find words by detecting stressed syllables and treating them as word onsets or offsets.

1. Introduction

The ability to find words from fluent speech is crucial for learning language. This is so because words are rarely produced in isolation, even in speech addressed to infants (Aslin, 1993; Brent & Siskind, 2001; van deWeijer, 1997). In this paper, we investigated infants' ability to find words in a non-native language, a critical first step in investigating the bases of bi/multilingual acquisition in infancy. This is particularly important given that there are more children growing up bilingual than monolingual (Associated Press, 2001; Grosjean, 2010), and infants' success at finding words has been found to be positively correlated with later language outcomes (Cristia, Seidl, Junge, Soderstrom, & Hagoort, 2014; Höhle, Pauen, Hesse, & Weissenborn, 2014; Newman, Rowe, & Ratner, 2015; Singh, Reznick, & Xuehua, 2012).

Previous cross-linguistic research shows that early in development, infants rely on statistical cues to find words (Goodsitt, Morgan, & Kuhl, 1993; Pelucchi, Hay, & Saffran, 2009a, 2009b; Saffran, Aslin, & Newport, 1996). One such statistical cue is the probability of co-occurrence of syllables. Young infants' sensitivity to syllable co-occurrence probabilities has been typically demonstrated in artificial language experiments (e.g. Saffran et al., 1996). A *distributional learning* account predicts successful segmentation by infants in any non-native language, given sufficient information about syllable co-occurrence probabilities.

With increasing age, infants' ability to find words in fluent speech is

affected by their language experience (*English*: e.g., Bortfeld, Morgan, Golinkoff, & Rathbun, 2005; Jusczyk & Aslin, 1995; Polka & Sundara, 2012; *German*: Höhle & Weissenborn, 2003; *Dutch*: Houston, Jusczyk, Kuijpers, Coolen, & Cutler, 2000; *French*: Goyet, Nishibayashi, & Nazzi, 2013; Nishibayashi, Goyet, & Nazzi, 2014; Nazzi, Iakimova, Bertoncini, Frédonie, & Alcantara, 2006; Nazzi, Mersad, Sundara, Iakimova & Polka, 2014; Polka & Sundara, 2012; Shi et al., 2006; *Spanish & Catalan*: Bosch, Figueras, Teixidó, & Ramon-Casas, 2013). For instance, English-learning 8-month-olds segment two-syllable words with stress on the first syllable (trochees e.g., *hamlet* and *kingdom*) but not two-syllable words with stress on the second syllable (iambs, e.g., *guitar* and *beret*; Jusczyk, Houston, & Newsome, 1999). Analysis of conversational speech shows that 90% of content words in English begin with a stressed syllable (Cutler & Carter, 1987). Thus, English-learning infants segment words within the first year of life by treating stressed syllables as onsets (*Metrical Segmentation Strategy*, Cutler & Norris, 1988).

In addition to stress, infants also use other language-specific cues like the coarticulation between syllables (Johnson & Jusczyk, 2001), probability of sound sequences or phonotactics (Mattys, Jusczyk, Luce & Morgan, 1999) as well as the differences in the instantiation of consonants and vowels or allophonic variation (Jusczyk, Hohne, & Baumann, 1999).

Due to its strong bases in language experience, it has been proposed that word segmentation abilities of infants, like those of adults, cannot be transferred to all languages. One account predicts the success or

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failure of word segmentation in a non-native language based on differences in the rhythm of languages (e.g., Cutler, Mehler, Norris, & Segui, 1986, 1992; more recently Murty, Otake & Cutler, 2007). The *rhythm* hypothesis differs crucially from a *distributional learning* account in that it explicitly predicts that infants' ability to find words is likely facilitated in some but not all bi/multilingual contexts.

Over the last century, there have been several attempts to classify languages into one of three rhythm classes – stress-timed (e.g. English, German, Dutch), syllable-timed (e.g. Spanish, French, Italian) and mora-timed (e.g. Japanese, Kannada). Early rhythm classification was based on prosodic and phonological characteristics of languages (Abercrombie, 1967; Dauer, 1983; Pike, 1946), but more recent attempts have focused on the durational properties of vocalic and intervocalic segments (Dellwo & Wagner, 2003; Ling, Grabe, & Nolan, 2000; Ramus, Nespor, & Mehler, 1999; White & Mattys, 2007).

Despite controversy as to how successfully (if at all) rhythm metrics capture cross-category distinctions in rhythm (Arvaniti, 2009; Grabe & Ling, 2002; Ramus et al., 1999; White & Mattys, 2007; Wiget et al., 2010), categorization into rhythm classes has proved useful to explain human performance on speech perception tasks. For instance, newborns are able to distinguish languages from different, but not the same rhythm class (Mehler et al., 1988; Nazzi, Bertoncini, & Mehler, 1998; Ramus, Hauser, Miller, Morris, & Mehler, 2000); and adults learning languages from different rhythm classes have been shown to rely on different units for word segmentation (for a review see Cutler, 2005). Given fundamental differences in the unit for word segmentation, word segmentation skills are likely transferable within- rather than between-rhythm classes.

According to Cutler et al.'s *rhythm hypothesis*, monolingual infants, like adults, should segment words in a rhythmically-similar, but not a rhythmically-different language. The extant research on cross-linguistic word segmentation is consistent with the *rhythm hypothesis*. Thus, monolingual English- and Dutch-learning 9-month-olds can segment two-syllable words in both languages (Houston et al., 2000), presumably because Dutch and English are rhythmically similar. Further, monolingual English- and French-learning 8-month-olds fail to segment two-syllable words in the other, rhythmically-different language (Polka & Sundara, 2012).

Although the rhythm hypothesis captures the ease of segmenting a non-native language, Dutch, these results also do not rule out a *distributional learning* account. In experiments on cross-language segmentation infants are typically tested using a natural language paradigm where they are familiarized for about 1 min to words in either their native or a non-native language. It is conceivable that infants might well succeed in segmenting unfamiliar, non-native languages using distributional cues given longer familiarization times. Under this account, English-learning infants fail to segment French two-syllable words with short familiarization durations, because they are unfamiliar with the language; but they are likely to succeed with extended familiarization.

Experiments by Pelucchi and colleagues lend support to the idea that infants succeed in segmenting in a rhythmically-different, non-native language with longer familiarization times (Pelucchi, et al., 2009a, 2009b). Using artificial language learning paradigms with an extended familiarization period of 2–3 min, Pelucchi et al. showed that English-learning 8-month-olds successfully segmented trochees in Italian.

Pelucchi et al.'s choice of Italian is intriguing in that despite Italian being classified as a syllable-timed language like Spanish and French, the prosodic properties of Italian are quite similar to those of English (White, Payne, & Mattys, 2009). First, like in English, the duration of vowels in stressed and unstressed syllables in standard Italian varies systematically. Stressed vowels, particularly in open syllables, are longer than unstressed vowels, and this difference in duration is especially salient in the penultimate position (Bertinetto, 1980; D'Imperio & Rosenthal, 1999; van Santen & D'Imperio, 1999; Vayra et al., 1984). In

fact, these vowel duration differences serve as primary cues to stress perception for Italian adults (Bertinetto, 1980). Second, like in English, in some dialects of Italian, vowel quality, specifically vowel reduction, is an important component of stress realization (Vayra et al., 1999; White et al., 2009). These two factors make the durational profile and acoustic instantiation of stress in Italian similar to that of English. Consequently, based on durational variation captured by rhythm metrics, Italian is intermediate between English, a stress-timed language, and Spanish, the prototypical example of a syllable-timed language (White et al., 2009).

To summarize, existing cross-language segmentation data from English-learning infants are somewhat consistent with both the *rhythm* hypothesis as well as a *distributional learning* account. If infants' word segmentation abilities transfer to rhythmically-similar but not rhythmically-dissimilar non-native languages, then we can account for English-learning infants' success in segmenting two-syllable words in Dutch, but not French. Infants' success in segmenting Italian bisyllabic words, albeit with a longer familiarization duration, might then be accounted for by the *rhythm hypothesis* because Italian is less similar rhythmically to English than Dutch, but more so than French.

Under a *distributional learning* account, English-learning infants successfully segment a non-native language Italian, with a longer familiarization phase, but not a non-native language French, with a shorter familiarization phase. What is problematic then is English-learning infants' success at segmenting Dutch, another non-native language, even with short familiarization duration.

These results are also consistent with a third, *Metrical Segmentation* account. The bisyllabic words used to test Dutch as well as Italian word segmentation were trochaic. In contrast, the bisyllabic words used to test French segmentation were, if anything, iambic. Thus, English-learning infants' attested difficulties in treating stressed syllables as word offsets (Jusczyk, Hohne, et al., 1999; Jusczyk, Houston, et al., 1999) alone could account for their failure in segmenting French, but not Dutch or Italian.

Finally, the extant research is consistent with a fourth, *lexical stress* account. Under this account, English-learning infants succeed in segmenting words only in languages where stress is used at the word level, as in English. This would account for their success in segmenting Dutch and Italian, but not French. French, unlike English, Dutch or Italian, does not use stress at the word level. Instead, in French, final syllables of words are stressed, but only if they are at the end of a phrase.

In Part I, we report results from four experiments to adjudicate whether the *rhythm* hypothesis, the *distributional learning* account, the *Metrical Segmentation* account, or the *lexical stress* account better explains infants' segmentation in a non-native language. For this we tested monolingual English 8-month-olds' ability to find bisyllabic words in two syllable-timed languages, French and Spanish. Although French bisyllabic words may be iambic — if they have any stress at all — Spanish has lexical stress and bisyllabic words can be either trochaic or iambic. We tested infants on both kinds of words in Spanish. We used a natural language paradigm and hypothesized as follows. If the *rhythm* hypothesis is correct, then English-learning 8-month-olds should fail to segment in both Spanish and French, regardless of the length of familiarization. If the *distributional learning* account is correct, then English-learning 8-month-olds were expected to segment in both French and Spanish with long, but not short familiarization durations. If the *Metrical Segmentation* account is correct, English-learning infants were expected to succeed in segmenting Spanish trochees, but not iambs in either Spanish or French. Finally, if the *lexical stress* account is correct, English-learning infants were expected to segment trochees and iambs in Spanish but not in French. Then, in Part II, experiments 5–7, we investigated the nature of English-learning infants' representation of newly segmented words in Spanish.

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