# Harmonic Cues in Speech Segmentation: A cross-linguistic Corpus Study on Child-directed Speech

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### 1. Introduction

Research on speech segmentation has shown that infants rely heavily on prosodic cues when they are segmenting words in a string of speech (Cutler & Norris 1988; Jusczyk, Houston & Newsome 1999; Morgan 1996; Jusczyk 1997, 1999; Curtin et al. 2005, among others). Statistical probabilities and phonotactic constraints, i.e., constraints in the order of phones are also observed to be helpful in word segmentation (Brent & Cartwright 1996; Safran, Newport & Aslin 1996; Aslin, Saffran & Newport 1998, among others). It seems natural to assume that other phonological regularities, for instance, vowel harmony in harmonic languages, may contribute to word segmentation as well. Assuming that a majority of words are harmonic in a language (having only back or only front vowels within word boundaries), vowel shifts from [-back] to [+back] or vice versa may signal a word boundary. In (1) below, which is the first utterance of the Turkish corpus (Aksu, 1aa.cha) at CHILDES, shifts from [-back] to [+back] and from [+back] to [-back] overlap with word boundaries which are marked with #.

1.	e	rel	cim	bu			ne
[-b	ack	[-bao	ck][-back]	#	[+back]	#	[-back]

Indeed, studies conducted with artificial languages based on Finnish and Turkish vowel harmony rules showed that adult speakers could recognize words on the basis of such harmony cues (Suomi, McQueen & Cutler 1997; Vroomen, Tuomainen & Gelder 1998; Kabak, Maniwa & Kazanina 2010). In these studies, artificial languages are created based on natural vowel harmony rules where word boundaries and harmony shifts perfectly overlap and adults were observed to be sensitive to such shifts. Results of head-turn experiments with children further showed that seven-month-old infants were sensitive to vowel shifts in long strings of CV sequences and recognized harmonic sequences as words (Mintz & Walker 2006). These findings suggest that when harmonic information is available, children can use such information to assign word boundaries. The question that remains to be raised is whether natural speech has such reliable cues. Harmonic languages are never perfectly harmonic, that is, there are always some exceptions on vowel harmony rules, or the lexicon of harmonic languages always have

non-harmonic words as well. Therefore it is possible that the harmonic languages are not as harmonic as it has been assumed in the literature.

The goal of this study is then to figure out whether it is reasonable to assume that children acquiring harmonic languages receive reliable harmonic cues that could be used in speech segmentation. To this end, two harmonic languages are compared to each other, and contrasted with two non-harmonic languages. The study does not only provide information regarding the availability of harmonic cues, it also shows how generalizable the results are through a cross-linguistic comparison.

## 2. Procedure

Parallel analyses were conducted on child-directed speech in two harmonic (Turkish, Hungarian) and two non-harmonic languages (Farsi, Polish) that are available at CHILDES. Similar amount of data (in terms of number of utterances) from each language were analyzed individually. Details of the data are reported in Table 1 below.

Language type	H	armonic	Non-harmonic	
Language	Turkish	Hungarian	Farsi	Polish
CHILDES Corpus	Aksu	MacWhinney	Family (Leila)	Weist
Age range of CHI	2;0-4;8	2;3-2;10	1;11-2;10	1;7-3;2
No. of utterances	10,232	11,478	13,325	13,258
No. of word tokens	34,391	41,514	40,472	130,778

**Table 1:** Corpus information for Turkish, Hungarian, Farsi and Polish.

At first, the most frequent 200 multisyllabic words were selected from each language and were coded as harmonic or non-harmonic. The reason for this selection was to exclude very low frequency words. Those words that have only back vowels or only front vowels were coded as harmonic. Those words that have a mixture of front or back vowels were categorized as non-harmonic.

In the second analysis, which was run on the whole corpora, word boundaries were coded as harmonic or non-harmonic. Non-harmonic word boundaries were those cases where a word that has a front vowel at the last syllable is followed by a word that has a back vowel in the initial syllable, or vice versa. An example of a non-harmonic word boundary is seen in (1) above. Harmonic word boundaries have the same type of vowel (either back or front) on both sides of the word boundary.

For the last phase of the analysis, which looks at the same data from a different angle, all possible vowel pairs (/aa/, /ai/, /ao/ etc.) were coded as harmonic or non-harmonic and then the frequency of these sequences within words (VV) and across words (V#V) were compared.

# 3. Results

The results of the first analysis, based on the most frequent 200 words in each language, suggest that a great majority of words are harmonic in harmonic languages. Although non-harmonic words are found in both Hungarian and Turkish, just as predicted, harmonic words are in majority. No such tendency is observed in Polish, where about half of the words were harmonic and the other half were not. An opposite pattern is observed in Farsi, where non-harmonic words were more frequent. Figure-1 below shows all four languages together for comparison. The scores displayed in the Figure are the percentages.



Figure 1: Harmonic vs. non-harmonic words in harmonic and non-harmonic languages

The second analysis that examines the word boundaries suggest that about 50% of word boundaries are harmonic in both harmonic and non-harmonic languages, as seen in Figure 2. These results, the latter one in particular, are problematic for a word segmentation mechanism based on vowel harmony cues. Before we give up on the idea of speech segmentation mechanism based on vowel harmony, we look at the same data from another perspective.





The results suggest that harmonic sequences are more likely to appear *within words* (VV), and non-harmonic sequences are mostly found at boundaries (V#V) in harmonic languages. Figure 3 presents the results of the harmonic languages. The results in harmonic languages contrast with the results in non-harmonic languages. As clearly seen in Figure 4, there is no difference between *within word* (VV) and *across word* (V#V) occurrences in non-harmonic languages.

Figure 3: Harmony within (VV) versus across (V#V) word boundary in harmonic languages.







## Conclusion

Natural harmonic languages, but not the non-harmonic ones, provide a learner with harmonic cues for word segmentation, although these cues are not as perfect as the ones created in the experiments. Therefore, harmonic cues, especially when they are used together with other cues, such as word stress, distributional properties of words, or morphemes, could potentially be useful in word segmentation. These results correctly predict that speakers of harmonic languages, but not the non-harmonic ones, rely on harmony cues in speech segmentation (Kabak, Maniwa & Kazanina 2010).

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