Position and vowel quality effects in infants' segmentation of vowel-initial words

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ABSTRACT

Recent studies have argued that English-learning infants' ability to segment vowel-initial (V-initial) words is seriously delayed with respect to their ability to segment consonant-initial (C-initial) words and that segmentation of V-initial words may occur as late as 16-months of age [1], [2], [3]. In contrast, infants' abilities to segment most C-initial words are well intact by 7.5-months [4]. We investigated both phonetic and phonological explanations for researchers' failure to find evidence for the segmentation of V-initial words before 16-months. We found that V-initial words may be segmented as young as 11-months of age and that although vowel-quality did not affect ease of segmentation, V-initial words were segmented more readily when they occurred sentence-initially and hence were acoustically more prominent. This finding combined with the lack of a finding of a simple preference for C-initial over V-initial words provides evidence for a phonetic explanation for infants' difficulty with V-initial words.

1.   INTRODUCTION

Several studies have addressed young infants' ability to segment C-initial words from the context of fluent speech. Jusczyk and Aslin, (1995) showed that English-learning infants as young as 7.5 months were able to segment C-initial words such as "cup" and "dog" from fluent speech [4]. Studies such as this one use words with clear acoustic landmarks, however, all words do not have such clear landmarks. Recent work has suggested that V-initial words with less clear landmarks may not be segmented till as late as 16 months of age [1], [2], [3]. It is important to learn why segmentation of these words is comparatively late in development, especially because some of toddlers' earliest productions are V-initial words (e.g., apple).

In this paper we consider two explanations for an initial difficulty in segmenting V-initial words. The first explanation we consider is that infants' difficulty with V-initial words is conditioned by phonological factors.

Alternative 1: Infants' difficulty with V-initial words is phonologically conditioned.

One possible phonological argument for the difficulty with V-initial words is that infants may be guided by a rule/constraint against onsetless words (in Optimality Theoretic terms, the ONSET constraint [5]).   This alternative is in line with recent work [6] suggesting that young infants have a grammar in which markedness constraints dominate faithfulness constraints. In such a grammar, the ONSET constraint would be ranked quite high until input data forced (or did not force) a reranking with respect to this markedness and other faithfulness constraints.

Another plausible phonologically-based (and not dissimilar) argument is that infants have problems with these words because they are of low frequency in the input (as suggested by corpus studies mentioned in, [1], [7], [8], & [9]). We know based on much recent work that infants are extremely sensitive to the statistical regularities in the input language [10], [11]. Thus, it is plausible that because of their relatively infrequent exposure to V-initial words, infants' detection of such words in their linguistic environment is delayed [1].

The second alternative we consider is that infants' difficulty in segmenting V-initial words is phonetic.

Alternative 2: Infants' difficulty with V-initial words is phonetically conditioned.

More specifically, infants may have a difficult time perceiving the beginnings of V-initial words because they are less perceptually salient due to e.g., the lack of acoustic landmarks marking their boundaries [12]. This explanation is in line with findings from previous work [13] in which we found that infants are sensitive to juncture strength and could segment certain C-initial words more easily when they were, arguably, in phonetically more salient positions. In the present studies the V-initial words we are examining may undergo little or no reduction at high syntactic boundaries and are also more perceptually salient.

In addition, other factors such as the sonority difference between V-initial and C-initial words may effect infants' perception of these words. In order to investigate the hypothesis that differences in sonority may influence infants' perception of the initial vowel we compared infants' performance with high sonority vowels (e.g., [a], [o]) to infants' performance with lower sonority vowels (e.g., [I], [ɛ]).

A sort of intermediary hypothesis that involves both phonetic and phonological factors is that a phonological

rule/constraint on resyllabification influences or degrades infants' perception of these onsetless words. This argument may be supported by the finding that 12-month-olds are able to segment "win", even when it is *not* utterance-initial [14]. Clearly, the glide /w/ is close in sonority to a vowel, but nonetheless blocks resyllabification because it is a consonant. This leads us to conclude that it may not be sonority per se which causes infants' difficulty in segmenting V-initial words.

In order to adjudicate between these two overarching alternatives, i.e., phonetic vs. phonological, we examine whether infants' segmentation of V-initial words varies with the position of the word in the sentence. We looked at whether infants segment these words more easily in sentence-initial position. If infants' difficulty with V-initial words is *purely* phonological we would expect the difficulty with the segmentation of these words to hold regardless of position. However, if infants' difficulty is phonetic and hence more gradient, then the location of the word in the sentence may be relevant. This is particularly true when we consider that V-initial words occurring at high syntactic boundaries are more apt to be heavily glottalized [15], the vowels are more likely to be fully realized, and less likely to be resyllabified with the preceding consonant. These phonetic factors may not only serve to make the V-initial words at high syntactic boundaries more perceptible to infants, but may also show that segmentation of these words appears at a younger age when these conditions hold.

2. EXPERIMENT 1

In Experiment 1 we use the Headturn Preference Procedure (HPP) to investigate whether infants are able to segment V-initial words by 11-months if these words are in prominent positions.

In the HPP the infant sits in the center of the caregivers' lap on a chair in the center of a three sided booth. A red light and a speaker are mounted on the center of each side panel. A green light is located in the center of the front panel. At the start of a given trial the light on the center panel begins to flash. When the child is facing towards the center light a light will begin to flash on a side panel. When the infant turns her head toward that light, speech begins to play, and continues to play until she looks away from the light for more than two consecutive seconds. The experimenter observes the infant through a small hole in the booth. A button box is connected to a computer that controls the selection and presentation of stimuli and records the looking time to each stimulus (the dependent measure). Both caregiver and experimenter wear sealed headphones and listen to masking music during the course of the experiment. In this use of the procedure there is a familiarization period immediately followed by a test period. In the familiarization period speech is presented until the infant reaches a listening time criterion. In the test period speech samples are presented which contain or do not contain the target familiarization stimulus.

2.1 METHOD

Twenty-four infants were familiarized with passages containing six tokens of each of two target V-initial words. These words all occurred in the passages in sentence-initial position. After familiarization, infants were tested on four words in list form, two of which were not heard during familiarization. These words were presented in list form. There were two groups of infants in the experiment: Group 1 heard tense V-initial words (ash and eab) and Group 2 heard lax V-initial words (eff and igg) embedded in passages during familiarization.

Example of familiarization passage for Group 1:
Eff runs a circus in Toronto. **Eff** hires acrobats to run the show.

Example of familiarization passage Group 2:
Ash makes me smile in spring. *Ash* learned how to do flips from me.

Test words: Eff, igg, ash, and eab.

2.2 RESULTS

Mean listening times towards familiar and unfamiliar test words were calculated for each of the 24 subjects. 18 of 24 subjects had longer average orientation times for familiar over unfamiliar test items. A mixed design ANOVA, 2 (test item type: familiar & unfamiliar) X 2 (vowel quality) revealed a significant main effect of test item type, $F(1,22)=4.95$, $p<.05$. In addition, there was no effect of vowel quality, $F(1,22)=.04$, $p>.1$, and no interaction between Test Item Type and Vowel Quality, $(F(1,22),p=.1)$. As Figure 1 illustrates, these effects were attributable to longer orientation times to familiar words (M=7.2, SD=2.6) than unfamiliar words (M=6.4, SD=2.7). These results provide the first evidence that infants as young as 11-months segment V-initial words when these words are presented sentence-initially.
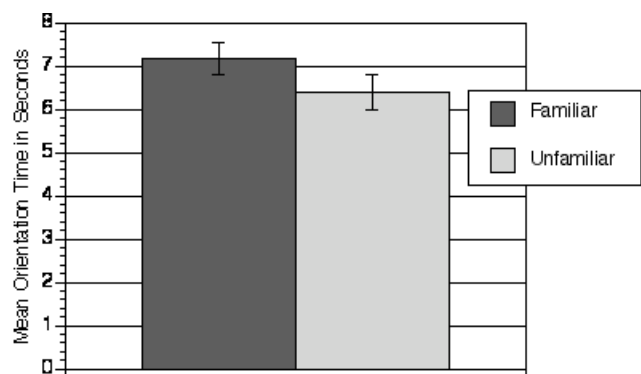

Figure 1: V-initial words sentence-initially

3. EXPERIMENT 2

Experiment 2 differed from Experiment 1 in only one respect: All target words occurred sentence-medially.

Example of familiarization passage for Group 1:
I like how **Eff** runs the circus. They say **Eff** hires clowns all year.

Example of familiarization passage for Group 2:
Somehow *Ash* makes us laugh. I'm sure *Ash* learned to do flips.

Test words and lists were the same ones used in Experiment 1.

3.1 RESULTS

Mean listening times towards familiar and unfamiliar test words were calculated for each of the 24 subjects. 14 of 24 subjects had longer average orientation times for familiar over unfamiliar test items. A mixed design ANOVA, 2 (test item type: familiar and unfamiliar) X 2 (vowel quality) revealed no significant main effect of test item type, $F_{(1,22)}=.31$, $p>.1$. In addition, there was no effect of vowel quality, $F_{(1,22)}=.2.51$, $p>.1$, and no interaction between Test Item Type and Vowel Quality, ($F_{(1,22)}$, $p=.1$). As Figure 2 illustrates, these results were attributable to similar orientation times to familiar (M=6.81, SD=2.6) and unfamiliar words (M=6.51, SD=2.9).
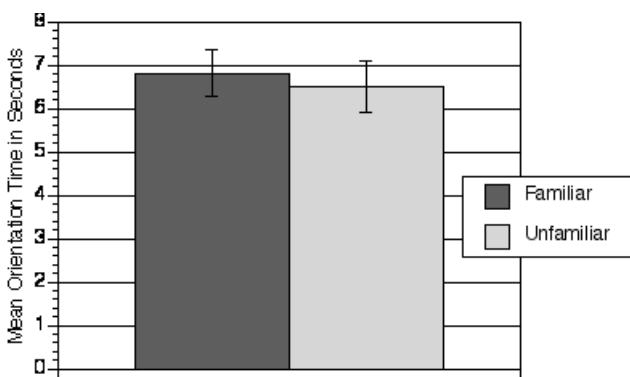

Figure 2: V-initial words sentence-medially

3.2 DISCUSSION

These results suggest that infants' inability to segment V-initial words may result from perceptual factors. Specifically, infants were able to segment V-initial words only when they were in phonetically strong positions (Exp 1). However, there might also be a phonological explanation for this finding: Because vowels are more apt to be glottalized sentence-initially [15], it could be that these English-learning infants have not yet realized that a glottal stop is not phonemic, or even if they realize this are still at a point (as suggested in [6]) at which markedness constraints domminate faithfulness constraints. If either of these phonological explanations were viable we would expect that infants at this age would show a clear preference for words with no violations of ONSET over words that violate this constraint. Assuming that glottal stop may be able to be phonemic in at least a limited sense

in the infant's grammar, in Experiment 3 we investigate the hypothesis that infants' ability to segment V-initial words sentence-initially is due to a phonologically-based preference for words with onsets.

4. EXPERIMENT 3

In previous studies of vowel segmentation infants' performance on V-initial words was compared, not to other V-initial words, but to C-initial words [1], [3]. It may be that infants simply prefer C-initial words to V-initial words and that findings of difficulty with V-initial words are due to this preference.

In this experiment, we use the HPP to investigate whether infants' difficulty with the V-initial words in medial positions is due to a phonological preference for C-initial words. We vary vowel sonority as well in the experiment to find out whether any preference for V- over C-initial words is gradient/phonetic or categorical/phonological.

4.1 METHOD

Sixteen infants were tested on two blocks of each of 6 different word lists (2 stop C-initial lists, 2 V-initial and 2 sonorant C-initial lists). Two introductory music trials were followed by 3 blocks of 6 word lists. Each word list consisted of eight words. One of each of the word lists contained high vowels and the other contained low vowels.

4.2 RESULTS AND DISCUSSION

Mean listening times towards all 3 types of lists were calculated (see Figure 3): C-initial (M=10.02; SD=3.4), sonorant-initial (M=10.4; SD=3.4), V-initial (M=9.99; SD=2.58). A one-way repeated measures ANOVA revealed no significant main effect of list type, $F_{(1,22)}=.31$, $p>.1$. In addition, a planned comparison revealed that infants had no preference for tense versus lax V-initial lists, $F_{(1,15)}=.47$, $p>.1$.
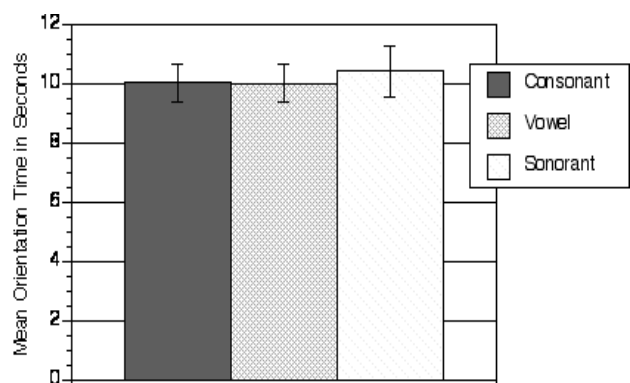

Figure 3: Preference for V-initial or C-initial words

5. GENERAL DISCUSSION

In this paper, we considered two alternative explanations

for infants' difficulty in segmenting V-initial words. Our evidence seems to favor a phonetic explanation for this difficulty. We found that by 11 months, infants were able to segment V-initial words in prominent positions where they were more apt to be fully realized and glottalized. In contrast, infants were not able to segment V-initial words when the vowels were less fully realized and less likely glottalized. The explanation for this cannot be purely phonological because, as shown in Experiment 3, there is no clear preference for C-initial over V-initial words.

In addition, our explanation cannot be purely one of phonological or phonetic sonority because in none of these experiments was vowel quality a factor effecting ease of segmentation. If sonority were a factor (even phonetically) we might expect to find a graded preference for low sonority V-initial words over high sonority V-initial words. We found no such preference and therefore cannot rely on sonority to explain infants' difficulty segmenting V-initial words.

One key difference between this study and previous studies may explain infants' success in Experiment 1: In previous studies, target V-initial words occurred only sentence medially [1] and juncture effects could not be measured. These words were less subject to glottalization and more subject to reduction —we found that infants *are* sensitive to the placement of target words in a sentence.

5. FURTHER DIRECTIONS

Recent work has provided substantial information on infants' ability to segment C-initial words ([1], [13], inter alia). In this paper we have sought to extend the literature on infant word segmentation by looking in detail at the segmentation of V-initial words. We have provided evidence for a phonetic explanation for English-learning infants difficulty with V-initial words. Given that phonetic constraints vary across languages further investigation may reveal that V-initial words are segmented more easily in learners of languages with different language specific phonetics than English.

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