English-learning Infants' Segmentation of Verbs from Fluent Speech

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pitch accent

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Abstract

Two experiments sought to extend the demonstration of English-learning infants' abilities to segment nouns from fluent speech to a new lexical class: verbs. Moreover, we explored whether two factors previously shown to influence noun segmentation, stress pattern (strong-weak or weak-strong) and type of initial phoneme (consonant or vowel), also influence verb segmentation. Our results establish the early emergence of verb segmentation in English: by 13.5 months for strong-weak consonant- or vowel-initial verbs and for weak-strong consonant-initial verbs; and by 16.5 months for weak-strong verbs beginning with a vowel. This generalizes previous reports of early segmentation to a new lexical class, thereby providing additional evidence that segmentation is likely to contribute to lexical acquisition. The effects of stress pattern and onset type found are similar to those previously obtained for nouns, in that verbs with a weak-strong stress pattern and verbs beginning with a vowel appear to be at a disadvantage in segmentation. Finally, we present prosodic analyses that suggest a possible effect of prosodic boundary and pitch accent distribution on segmentation. These prosodic differences potentially explain a developmental lag in verb segmentation observed in the present study compared to earlier findings for noun segmentation.

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1 Introduction

A crucial step in speech processing for infants, as well as adults, is word segmentation, or the extraction of the sound patterns of words from the speech signal. For infants, the process of word segmentation is believed to be important for language acquisition, since speech addressed to infants is usually made up of sentences rather than isolated words (Aslin, 1993; Brent & Siskind, 2001; van de Weijer, 1998). Because the acoustic marking of word boundaries in the speech signal is not systematic (Cole & Jakimik, 1978, 1980; Klatt, 1979, 1989), understanding the factors involved in early word segmentation contributes to an understanding of the language acquisition process more generally. In this paper we investigate some factors relating to the segmentation of verbs, a lexical class which has previously not been studied, as a preliminary step in evaluating some hypotheses relating to the acquisition of lexical classes more generally.

How can infants segment speech into words if word boundaries are not systematically marked by a single reliable acoustic marker? Lexical boundaries are signaled in speech by a number of different linguistic cues. These include prosodic cues (the distribution of stressed syllables and phrasal boundaries), allophonic cues (the realization of some phonemes depending on their position within words), phonotactic cues (constraints on phoneme order within words), and distributional cues (higher transitional probabilities within words compared to between words). While none of these cues alone is sufficient to properly segment fluent speech, successful segmentation should be possible if these cues are used in conjunction. In the following paragraphs we review previous work showing that infants perceive and utilize these cues in speech segmentation. We then discuss why understanding the segmentation process can inform hypotheses about lexical acquisition, and how this led us to study the segmentation of verbs.

Several studies have established that young English-learning infants are perceptually sensitive to the linguistic cues discussed above, and that they use them in segmenting speech. The early acquisition of certain prosodic properties is suggested by the emergence of a preference for words with the predominant English strong-weak (SW) stress pattern (e.g., *porter*) over less frequent weak-strong (WS) words (e.g., *report*) between six and nine months (Jusczyk, Cutler, & Redanz, 1993a; Turk, Jusczyk, & Gerken, 1995). A sensitivity to allophonic differences was found in infants as young as two months of age (Hohne & Jusczyk, 1994), as attested by their ability to discriminate between pairs such as *nitrate* and *night rate*. Infants appeared to become sensitive to phonotactic properties between six and nine months of age (Jusczyk, Friederici, Wessels, Svenkerud, & Jusczyk, 1993b; Jusczyk, Luce, & Charles-Luce, 1994; Mattys, Jusczyk, Luce, & Morgan, 1999; see also Friederici & Wessels, 1993, for similar data on Dutch-learning infants), as shown by the emergence of a preference for legal or frequent sequences of phonemes (e.g., *chun*) in their native language compared to illegal or infrequent ones (e.g., *yush*).

Recent work focusing on the use of these linguistic cues at different ages has highlighted the importance of prosody, that is, lexical stress, at the onset of word segmentation. The use of prosody is attested by the fact that infants begin segmenting nouns with the predominant SW stress pattern (e.g., *candle*) at 7.5 months, while they start segmenting WS nouns (e.g., *guitar*) at only 10.5 months (Jusczyk, Houston, & Newsome, 1999b; see also Echols, Crowhurst, & Childers, 1997; Houston, Santelmann, & Jusczyk, 2004; Johnson & Jusczyk, 2001; Morgan & Saffran, 1995). Accordingly, it was proposed that these young infants use a prosodic segmentation procedure that posits word boundaries before every strong syllable in the signal, a procedure corresponding to the "metrical segmentation strategy" found to be used by adult native speakers of English (Cutler, Mehler, Norris, & Segui, 1986; Cutler & Norris, 1988; McQueen, Norris, & Cutler, 1994), which might develop from infants' early sensitivity to rhythm (Nazzi, Bertoncini, & Mehler, 1998; Nazzi, Jusczyk, & Johnson, 2000). Infants at about eight months of age were also shown to use distributional cues to segment words, but infants seemed to give more weight to prosodic than to distributional information (Jusczyk et al., 1999b). The use of distributional information at around eight months is further attested by the finding of the use of transitional probabilities in the order of syllables presented in a continuous sequence to group syllables into cohesive word-like units (Saffran, Aslin, & Newport, 1996; see also Jusczyk et al., 1999b, for similar findings, and Brent & Cartwright, 1996; Dahan & Brent, 1999; Johnson & Jusczyk, 2001; Perruchet & Vinter, 1998 for a discussion of these findings). Finally, at about 10.5 months, infants also appear to use allophonic (Jusczyk, Hohne, & Bauman, 1999a), phonotactic (Mattys & Jusczyk, 2001a), and phonological phrase boundary cues (Gout, Christophe, & Morgan, 2004) to segment fluent speech.

The studies described above have begun to trace the picture of the early emergence of word segmentation in English, showing that infants use a combination of cues, the relative importance of which changes with development. However, many questions remain. In particular, all studies on word segmentation conducted so far in English have focused on the segmentation of nouns (or pseudowords) to the exclusion of every other lexical class (see however Höhle & Weissenborn, 2003, for evidence of closed-class word segmentation at 8 months in German).

The main goal of the present study was to start tracing the early segmentation of English words from other lexical classes. Because of the importance of the noun/verb distinction, not only in linguistics but also in developmental psycholinguistics, the focus of the present study is on *verbs*. Besides determining when verbs start to be segmented, we were interested in evaluating whether some of the factors found to have an early impact on noun segmentation also have an impact on verb segmentation. In particular, two factors were investigated here: stress pattern and the type of segment at word onset.

First, we evaluated whether stress pattern, which is one of the earliest cues used to segment words, has an impact on verb segmentation. Exploring this issue seemed important, given that bisyllabic verbs, contrary to bisyllabic nouns and bisyllabic words in general, do not predominantly have a strong-weak stress pattern (Cassidy & Kelly, 1991; Cutler & Carter, 1987; Kelly & Bock, 1988). This is clearly illustrated by the findings of Kelly and Bock (1988), which showed that in a representative sample of English bisyllabic words (3000 nouns and 1000 verbs), the majority of the verbs (i.e. 69%) had a WS stress pattern, while the majority of nouns (i.e. 94%) had a SW pattern; conversely, most of SW words (i.e., 90%) were nouns, while most of the WS words (i.e., 85%) were verbs. One hypothesis that might be formulated is that these statistical differences have an effect on segmentation abilities (assuming that infants can distinguish between nouns and verbs at this age), so that stress pattern has a differential impact on noun versus verb segmentation. On the contrary, we predicted based on our earlier proposal that the prosodic strong-weak segmentation procedure emerges from infants' early sensitivity to linguistic rhythm (Nazzi et al., 1998, 2000) that the strong-weak bias found for nouns (Jusczyk et al. 1999b) should generalize to all lexical classes, even those for which the opposite stress pattern predominates. Accordingly, we predicted that the strong-weak bias would replicate for verbs.

Second, we evaluated the impact of the nature of the initial phoneme of a word on segmentation. Previous work with nouns had suggested that segmentation is mediated by the type of onset. In particular, nouns with vocalic onsets were not found to be segmented before 16.5 months of age (Mattys & Jusczyk, 2001b), while nouns with consonantal onsets are already segmented by 8 months of age (Jusczyk & Aslin, 1995; Jusczyk et al., 1999b; Mattys & Jusczyk, 2001b). Given the magnitude (8-month developmental lag) of the onset type effect found by Mattys and Jusczyk (2001b), it appeared important to try and replicate this effect in a different study, hence the inclusion of this dimension in the present study.

To address these issues, two experiments explored the segmentation of bisyllabic verbs from speech by infants of different ages, verbs which had a SW stress pattern (Experiment 1) or a WS stress pattern (Experiment 2). In both experiments, the type of onset (consonant- or vowel-initial) was manipulated in the stimuli. Each experiment used the version of the *headturn preference procedure* (HPP) adapted by Jusczyk and Aslin (1995) to explore infants' segmentation of verbs from fluent speech and ran as follows. Infants were first familiarized with a pair of target verbs, and then presented with four passages, two containing repetitions of each of the familiarized verbs, the other two containing two other verbs.[1] Given previous results using this procedure (Jusczyk & Aslin, 1995; Jusczyk et al., 1999b), if infants detect the occurrence of the familiarized verbs in the passages, they will orient significantly longer to these passages than to the ones with the unfamiliarized verbs. Several groups of infants were tested in Experiment 1 (verbs with a SW stress pattern), starting with 10.5-month-olds, and moving up in three-months increments (13.5 months) until the different types of words presented were all segmented.

1 In this kind of study, there are in fact two possible presentation orders, either isolated words first, or passages first. We used the words-first paradigm, as it has been used more often (a survey of the literature shows that the words-first order has been used in 43 published experiments, against 11 experiments for the passages-first experiment), and studies having directly compared both presentation orders always found converging results.

2 Experiment 1

2.1
Method

2.1.1
Participants

Forty-eight infants from American English-speaking families were tested and their data included in the analyses: 24 10.5-month-olds (mean = 321 days, range = 304 to 331 days; 7 males, 17 females), and 24 13.5-month-olds (mean = 404 days, range = 392 to 426 days; 10 males, 14 females). The data of 14 additional infants were not included in the analyses: seven 10.5-month-olds (becoming fussy or crying: 4; orientation times less than 3 s to the passages: 2; not turning to the lights: 1), and seven 13.5-month-olds (becoming fussy or crying: 6; orientation times less than 3 s: 1).

2.1.2
Stimuli

A female talker, who was a native speaker of American English, recorded four different six-sentence passages (see Appendix 1), one passage for each of the four target verbs. The selected verbs were: ticket, visit, orbit, and outlaw. All four verbs had a strong-weak stress pattern; two began with a consonant, two with a vowel. Each verb appeared in every sentence of its appropriate passage. The talker was encouraged to read the passages in a lively voice, as if reading to a small child. The recordings were made in a sound-attenuated room. The average duration of the passages was 22.75 s.

For each verb, the same talker also recorded 15 isolated occurrences (bearing 3rd person inflection, which was the form appearing in the passages) in a row for use in the familiarization phase. The talker was asked to repeat the items with some variation, in a lively voice as if addressed to an infant. All these lists were about 19.85 s long.

2.1.3
Procedure and apparatus

The experiment was conducted in a three-sided test booth made of pegboard panels. Except for a small section of preexisting holes in the front panel used for monitoring the infant's headturns, the panels were backed with white cardboard to prevent the infant from seeing behind the panels. The test booth had a red light and a loudspeaker (7-inch Advent) mounted at eye level on each of the side panels and a green light mounted on the center panel. Directly below the center light a five-centimeter hole accommodated the lens of a video camera used to record each test session. A white curtain suspended around the top of the booth shielded the infant's view of the rest of the room. A computer terminal (Macintosh Quadra 650) and response box were located behind the center panel, out of view of the infant. The response box, which was connected to the computer, was equipped with a series of buttons. The box was controlled by an observer hidden behind the center panel, who looked through a peephole and pressed the buttons of the response box according to the direction of the infant's headturns, thus starting and stopping the flashing of the lights and the presentation of the sounds. Information about the direction and duration of the headturns and the total trial duration were stored in a data file on the computer.

The observer was not informed as to the group to which the infant was assigned. Moreover, both the observer and the infant's caregiver wore earplugs and listened to masking music over tight-fitting closed headphones, which prevented them from hearing the stimuli presented.

A modified version of the HPP was used in the present study. Each infant was held on a caregiver's lap. The caregiver was seated in a chair in the center of the test booth. Each trial began with the green light on the center panel blinking until the infant had oriented in that direction. Then, the center light was extinguished and the red light above the loudspeaker on one of the side panels began to flash. When the infant made a turn of at least 30° in the direction of the loudspeaker, the stimulus for that trial began to play. Each stimulus was played to completion (i.e., when the 6 sentences in the passage had been presented) or until the infant failed to maintain the 30° headturn for two consecutive seconds (e.g., if the infant turned back to the center or looked at the mother, the floor, or the ceiling). The stimuli were stored in digitized form on the computer, and were delivered by seven-inch Advent loudspeakers via a 12-bit D/A converter, antialiasing filters and a Kenwood audio amplifier (KA 5700). If the infant turned away from the target by 30° in any direction for less than 2 s and then turned back again, the trial was continued but the time spent looking away was not included in the orientation time. Thus, the maximum orientation time for a given trial was the duration of the entire speech sample. The flashing red light remained on for the entire duration of the trial.

Each experimental session began with a familiarization phase in which infants heard repetitions of two of the targets on alternating trials until they accumulated 30 s of orientation times to each. If the infants achieved the familiarization criterion for one item, but not for the other, the trials continued to alternate until the criterion was achieved for both. The side of the loudspeaker from which the stimuli were presented was randomly varied from trial to trial.

The test phase began immediately after the familiarization criterion was attained. It consisted of four presentations of each of the four 6-sentence passages, hence leading to a total of 16 test trials. Each passage was presented once in each block. The order of the different passages within each block was randomized.

2.1.4
Design

At both ages, half of the infants heard the verbs ticket and orbit during the familiarization phase, and the other half heard the verbs visit and outlaw.

2.2
Results

2.2.1
Familiarization phase

In order to verify that there were no differences in target word exposure during familiarization for the different test conditions, mean familiarization times were calculated for each age group and onset type. A two-way ANOVA with the main between-subject factor of age (10.5 vs. 13.5 months), and the main within-subject factor of onset type (consonant- vs. vowel-initial) was conducted. There was no effect of age ($M = 38.63$s at 10.5 months, $M = 37.90$s at 13.5 months, $F(1, 46) < 1$), nor was there an effect of onset type ($M = 36.42$s for vowel-initial verbs, $M = 40.11$s for consonant-initial verbs, $F(1, 46) = 3.2$, $p = .08$). The interaction between the two factors also failed to reach significance, $F(1, 46) = 3.0$, $p = .09$.[2]

2.2.2 Test phase

Mean orientation times to the passages containing the familiarized and new verbs were calculated for each infant. The data are presented in Figure 1, broken down by age and onset type.

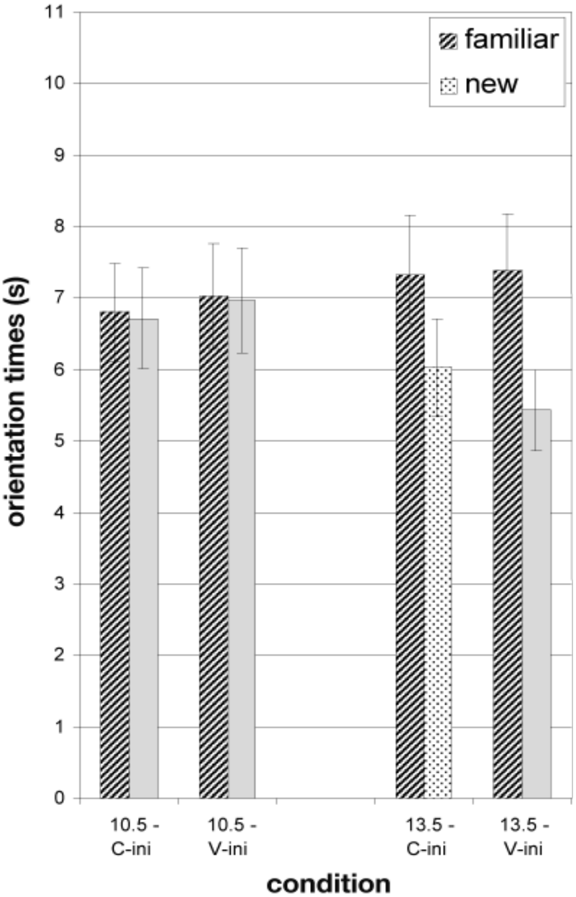

Figure 1

Mean orientation times to the test passages containing the familiarized and new strong-weak verbs (familiar vs. new, respectively), broken down by age (10.5 vs. 13.5 months) and onset type (consonant- vs. vowel-initial verbs) for Experiment 1. The arrows above and below each bar indicate the *SE* of the mean

2 Contrast tests revealed a significant difference between familiarization times to the vowel-initial ($M = 34.29$ s) and consonant-initial ($M = 41.50$ s) verbs at 13 months. However, even though the amount of familiarization differed for both conditions, segmentation was not affected as both onset types were segmented at that age.

After verification that the counterbalancing factor of group (familiarization with ticket/orbit vs. visit/outlaw) did not have an impact on performance, a three-way ANOVA with the main between-subject factor of age (10.5 vs. 13.5 months), and the main within-subject factors of familiarity (familiarized vs. new) and onset type (consonant- vs. vowel-initial) was conducted. There was a significant effect of familiarity, $F(1, 46) = 5.3$, $p = .03$, the infants having longer orientation times to the passages with the familiarized verbs, and a significant age × familiarity interaction, $F(1, 46) = 4.3$, $p = .04$. All other effects and interactions failed to reach significance (all $F(1, 46) < 1$), including the factor type of onset.

Given the interaction, the effect of familiarity was evaluated for both age groups. This effect was significant at 13.5 months, $F(1, 44) = 9.6$, $p = .003$, as attested by longer average orientation times for the passages containing the familiarized verbs ($M = 7.35$ s, $SD = 3.30$) than for the passages with the new verbs ($M = 5.73$ s, $SD = 2.59$). But the effect of familiarity was not significant at 10.5 months, $F(1, 44) < 1$, these infants orienting equally to the passages containing the familiarized verbs ($M = 6.92$ s, $SD = 2.96$) and the new verbs ($M = 6.84$ s, $SD = 3.13$).

2.3
Discussion

Infants in the present experiment displayed significantly longer orientation times to the passages containing the familiarized verbs. This indicates some early ability to segment verbs with a strong-weak pattern from fluent speech, thereby providing direct evidence for the extension to the lexical class of verbs of infants' early word segmentation abilities.

However, this effect interacted with age, and an examination of each individual age group revealed that the segmentation effect was due entirely to the 13.5-month-olds. Hence, the present results show that the strong-weak bisyllabic verbs used here begin to be segmented between 10.5 and 13.5 months of age. These findings contrast with previous results suggesting that strong-weak nouns begin to be segmented as early as 7.5 months of age (Jusczyk et al., 1999b). In the general discussion, we will make some speculations regarding the prosodic factors that might have contributed to this lag.

Second, onset type did not appear to affect segmentation performance: neither vocalic nor consonantal onsets were segmented at 10.5 months, while both were segmented equally well at 13.5 months. This finding contrasts with the one obtained for monosyllabic nouns (Mattys & Jusczyk, 2001b). The effect of onset type is further explored in the next experiment.

In the following experiment, we investigate infants' ability to segment (consonant- and vowel-initial) weak-strong bisyllabic English verbs from fluent speech. As for Experiment 1, several groups of infants were tested, starting at 10.5 months, and moving up in three-months increments (13.5 months and 16.5 months) until the different types of words presented were all segmented.

3 Experiment 2

3.1 *Method*

3.1.1 Participants

Eighty infants from American English-speaking families were tested and their data included in the analyses: 32 10.5-month-olds (mean = 319 days, range = 298 to 341 days; 11 males, 21 females), 24 13.5-month-olds (mean = 421 days, range = 395 to 438 days; 11 males, 13 females), and 24 16.5-month-olds (mean = 497 days, range = 463 to 519 days; 13 males, 11 females).[3] The data of 39 additional infants were not included in the analyses: 13 10.5-month-olds (becoming fussy or crying: 8; orientation times less than 3 s to the passages: 1; not turning to the lights: 2; falling asleep: 1; parental interference: 1), 19 13.5-month-olds (becoming fussy or crying: 10; orientation times less than 3 s: 7; not looking at the lights: 1; technical problems: 1), and 7 16.5-month-olds (becoming fussy or crying: 5; orientation times less than 3 s: 2).

3.1.2 Stimuli

The same female talker who recorded the stimuli used in the previous experiment recorded four different six-sentence passages (Appendix 2), one passage for each of four target verbs (discount, permit, incite, and import). All four verbs had a weak-strong stress pattern; two began with a consonant, two with a vowel. Each verb appeared in every sentence of its appropriate passage. The talker was encouraged to read the passages in a lively voice, as if reading to a small child. The recordings were made in a sound-attenuated room. The average duration of the passages was 23.50 s.

For each verb, the same talker also recorded 15 isolated tokens (bearing 3rd person inflection, which was the form appearing in the passages) in a row for use in the familiarization phase. The talker was asked to repeat the items with some variation, in a lively voice as if addressed to an infant. All these lists were about 20.00 s long.

3.1.3 *Procedure, apparatus and design*

The procedure and the apparatus were identical to those described in Experiment 1, except for one detail. While each passage was presented four times to the 10.5- and 13.5-month-olds, as done in Experiment 1, passages were presented only twice to the 16.5-month-olds, since most infants at that age would not sit through 16 test trials. At

[3] Twenty-four 10.5-month-olds were initially tested. Because there was a non-significant segmentation trend in one of the conditions (consonant-initial words), we tested eight more 10.5-month-olds in order to clarify the results. This manipulation reduced the initial trend. Although we report the analyses conducted with all 32 10.5-month-olds, note that similar results are obtained when analyzing only the data of the first 24 10.5-month-olds tested.

all ages, equal numbers of infants were randomly assigned into one of two groups, defined in terms of the verb pair (discount/incite vs. permit/import) presented during the familiarization phase.

3.2
Results

3.2.1
Familiarization phase

Again, in order to verify that there were no differences in target word exposure during familiarization for the different test conditions, mean familiarization times were calculated for the three age groups and the two onset types. A two-way ANOVA with the main between-subject factor of age (10.5 vs. 13.5 vs. 16.5 months), and the main within-subject factor of onset type (consonant- vs. vowel-initial) was conducted. There was no difference between the familiarization times at the three ages: 41.90 s at 10.5 months, 38.85 s at 13.5 months and 39.87 s at 16.5 months, $F(2, 77) = 2.3$, $p = .11$. There was also no effect of onset type (39.28 s for vowel-initial verbs, 41.13 s for consonant-initial verbs, $F(1, 77) = 1.8$, $p = .19$, and no significant interaction between the two factors, $F(2, 77) < 1$.

3.2.2
Test phase

Mean orientation times to the passages containing the familiarized and new verbs were calculated for each infant. The data are presented in Figure 2, broken down by age and onset type.

After verification that the counterbalancing factor of group (familiarization with discount/incite vs. permit/import) did not have an impact on performance, a three-way ANOVA with the main between-subject factor of age (10.5 vs. 13.5 vs. 16.5 months), and the main within-subject factors of familiarity (familiarized vs. new) and onset type (consonant- vs. vowel-initial) was conducted. There was a significant effect of age, $F(2, 77) = 3.7$, $p = .03$, the 16.5-month-olds having longer orientation times than the other two groups of infants. There was also a significant effect of familiarity, $F(1, 77) = 20.3$, $p < .001$, the infants having longer orientation times to the passages with the familiarized weak-strong verbs. Moreover, there was a significant age × familiarity interaction, $F(2, 77) = 4.6$, $p = .01$, and the interaction between familiarity and onset type approached significance, $F(1, 77) = 3.4$, $p = .07$. All other effects and interactions failed to reach significance.

Given the effects involving age, we conducted a two-way ANOVA with the main within-subject factors of familiarity (familiarized vs. new) and onset type (consonant- vs. vowel-initial) at all three ages.

At 10.5 months, there was no significant main effect of familiarity, $F(1, 31) < 1$, the infants displaying similar orientation times to the passages with the new verbs ($M = 6.39$ s, $SD = 2.35$) and to those with the familiarized verbs ($M = 6.07$ s, $SD = 2.38$). On the other hand, there was a significant effect of onset type, $F(1, 31) = 5.0$, $p = .03$, infants' orientation times to the passages with the vowel-initial verbs ($M = 6.75$ s, $SD = 3.22$) being significantly longer than those to the passages containing the

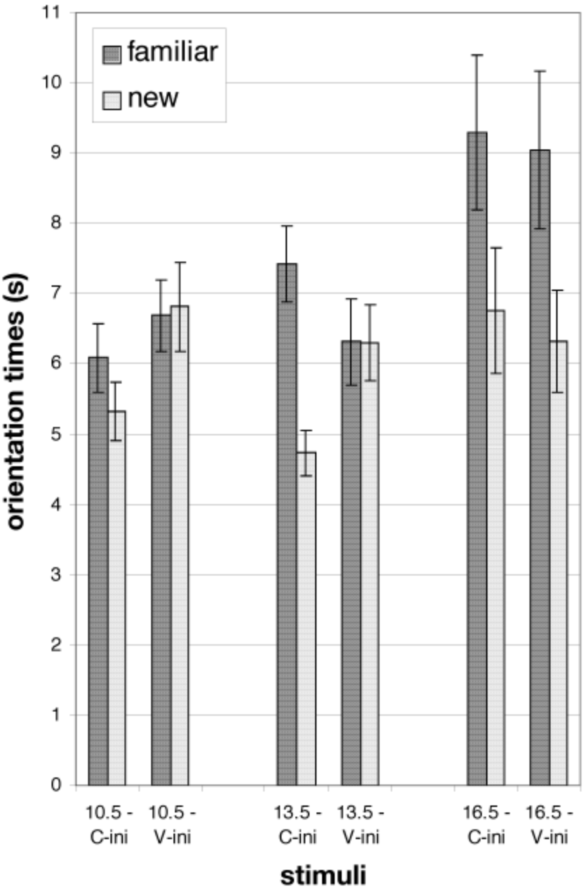

Figure 2

Mean orientation times to the test passages containing the familiarized and new weak-strong verbs (familiar vs. new, respectively), broken down by age (10.5 vs. 13.5 vs. 16.5 months) and onset type (consonant- vs. vowel-initial verbs) for Experiment 2. The arrows above and below each bar indicate the *SE* of the mean

consonant-initial verbs ($M = 5.70$ s, $SD = 2.58$). However, there was no interaction between familiarity and onset type, $F(1, 31) = 1.3$, $p = .27$.

At 13.5 months, there was a significant effect of familiarity, $F(1, 23) = 9.4$, $p = .005$, these infants having longer orientation times for the passages containing the familiarized verbs ($M = 6.87$ s, $SD = 2.10$) than for the passages with the new verbs ($M = 5.52$ s, $SD = 1.59$). There was no main effect of onset type, $F(1, 23) < 1$, but there was a significant interaction between familiarity and onset type, $F(1, 23) = 8.2$, $p = .009$. Contrast tests separating the data according to onset type revealed that infants' orientation times for the familiarized verbs were longer than those for the new verbs in the consonant-initial condition (7.42 s vs. 4.73 s, $F(1, 23) = 4.5$, $p = .007$), but not in the vowel-initial condition (6.31 s vs. 6.30 s, $F(1, 23) < 1$).

At 16.5 months, the only significant effect was that of familiarity, $F(1, 23) = 11.3$, $p = .003$, these infants having longer orientation times for the passages containing the familiarized verbs ($M = 9.17$ s, $SD = 4.62$) than for the passages with the new verbs ($M = 6.55$ s, $SD = 3.40$). Notably, the interaction between familiarity and onset type failed to reach significance, $F(1, 23) < 1$.

3.3 Discussion

Infants in the present experiment displayed significantly longer orientation times to the passages containing the familiarized verbs. This indicates some early ability to segment weak-strong verbs from fluent speech, thereby extending the results previously found for weak-strong nouns.

However, as in Experiment 1, this effect changed with age. The analyses conducted for each age group show that the 10.5-month-olds failed to segment the weak-strong verbs, in contrast to the 13.5- and 16.5-month-olds. Hence, the present data show that the weak-strong bisyllabic verbs used here start to be segmented between 10.5 and 13.5 months of age.

Moreover, the present experiment shows that the ability to segment weak-strong verbs at different ages was mediated by the type of onset. Infants aged 13.5 months demonstrated the ability to segment consonant-initial weak-strong verbs (discount and permit) but not vowel-initial weak-strong verbs (incite and import), while infants at 16.5 months could segment weak-strong verbs with either type of onset. This suggests that the vowel-initial weak-strong verbs, lacking clear acoustic discontinuities at their onsets, were more difficult to segment.

Finally, we found two unexpected effects. First, infants at 10.5 months oriented longer to vowel-initial verbs, independently of their familiarization status. We attribute this effect to a sampling artifact, which is indirectly supported by the fact that it is not replicated with older infants. Second, infants at 16.5 months had longer orientation times overall. We suspected that this effect was likely due to the fact that 16.5-month-olds were presented with 8 rather than 16 test trials, and that orientation times tend to decrease over the course of an experiment. Therefore, we conducted an additional analysis in which orientation times at all three ages were calculated based on the first eight test trials. This new analysis confirmed the significant effect of familiarity, $F(1, 77) = 22.3$, $p = .001$, and the significant age × familiarity interaction, $F(2, 77) = 4.0$, $p = .02$, but no other effect or interaction approached significance. In particular, the effect of age found previously was not replicated, infants having equivalent orientation times at all three ages (7.44, 7.07 and 7.86 s respectively). This analysis thus supports our interpretation that the longer orientation times for the older infants in the main analysis was due to the fact that orientation times tend to decrease over the course of an experiment.

4 General Discussion

The present study constitutes the first investigation of young infants' ability to segment verbs from fluent speech in English. Previous studies on early word segmentation in English had focused on either pseudowords (e.g., Saffran, Aslin, & Newport, 1996) or nouns (e.g., Jusczyk & Aslin, 1995; Jusczyk et al., 1999b), and it was unknown whether word segmentation abilities would generalize to lexical classes other than nouns. Our first finding is therefore a demonstration of infants' relatively early ability to segment several verb forms. Indeed, although infants failed to segment all four types of verbs (whether strong-weak or weak-strong, consonant- or vowel-initial) at 10.5 months, they were segmenting all but the weak-strong vowel-initial verbs at 13.5 months, and all four types at 16.5 months. In the following, we first discuss how the two factors investigated in this study—namely, onset type and stress pattern—affected verb segmentation by infants at different ages. Later on, relying on prosodic analyses of our stimuli and those of Jusczyk et al. (1999b), we will discuss reasons why evidence for verb segmentation in the present study could not be found before 13.5 months, as opposed to 7.5 months in previous studies on noun segmentation (Jusczyk et al., 1999b).

The second significant finding of the present study is that the type of word onset affects segmentation: words which began with vowels tended to be more difficult to segment than words which began with consonants. In this regard, the current study both replicates and extends previous work in important ways, while also raising several issues for future investigation, as discussed below. First, the existence of a developmental lag for segmenting words beginning with vowels as opposed to consonants was confirmed in these experiments. Previous results had shown using monosyllabic nouns that consonant-initial words are segmented by 8 months, while vowel-initial words are segmented by 16 months (Jusczyk & Aslin, 1995; Mattys & Jusczyk, 2001b). The present study showed likewise that infants at certain ages have more trouble segmenting vowel-initial items: 13.5-month-olds could segment weak-strong bisyllabic verbs beginning with consonants but not vowels. In contrast, 16.5-month-olds were able to segment all verb types examined in the current study, while 10.5-month-olds were able to segment none of the verb types in this study. While the present study confirms that words with vowel onsets can be harder to segment, it also finds a smaller developmental lag for the segmentation of vowel-initial words than previously reported by Mattys and Jusczyk (2001b). We will return to a discussion of differences in the size of the developmental lag in later discussion.

Why might words beginning with vowels be harder to segment than words beginning with consonants? On one hand, there is crosslinguistic evidence for a predominance of syllables starting with a consonant (Vallée, Rousset, & Boë, 2001). Just as infants become sensitive to the allophonic and phonotactic properties of their native language within their first year (Friederici & Wessels, 1993; Hohne & Jusczyk, 1994; Jusczyk et al., 1993a, 1993b, 1994; Mattys et al., 1999) and use them for segmentation (Jusczyk et al., 1999a; Mattys & Jusczyk, 2001b), they may develop a bias for segmenting consonant-initial syllables/words (see Peters, 1985, for a similar proposal). Moreover, there could be some resyllabification between the vowel-initial onset syllable and the preceding word that might change the syllabic structure of the vowel-initial word to be segmented (as found in French, in particular for the "liaison" phenomenon, Chevrot, Dugua, & Fayol, 2005; Wauquier-Gravelines, 2002). Alternatively, the present results could reflect the fact that words starting with phonemes characterized by clear acoustic discontinuities, such as plosive consonants, are easier to segment than words starting with continuous phonemes, such as vowels or continuous consonants. This latter explanation, contrary to the preceding ones, would predict that the disadvantage found for vowel-initial words would extend to words starting with fricatives and nasals for example, a prediction which will have to be systematically explored in future research.[4]

A third significant finding of the present study concerns evidence that bisyllabic words with a strong-weak pattern are more easily segmented than words with a weak-strong pattern. In particular, the present study showed that infants at 13.5 months segmented all strong-weak bisyllabic verbs, regardless of onset type, while they segmented only one type of weak-strong bisyllabic verb, those beginning with consonants (recall that infants at 10.5 and 16.5 months were able to segment none of the verbs and all of the verbs, respectively, in the present study). Further confirmation of the difficulty of segmenting weak-strong verbs comes from an additional 2 × 2 ANOVA on the 13.5-month-olds' performance with vowel-initial verbs. This analysis confirmed that for vowel-initial verb items, a strong-weak stress pattern facilitated segmentation relative to a weak-strong stress pattern, as revealed by a marginal interaction between familiarity and stress pattern, $F(1, 23) = 3.8, p = .06$. Findings that a strong-weak stress pattern facilitated segmentation by infants aged 13.5 months support a key prediction of Nazzi et al. (1998, 2000) regarding the emergence of rhythmic segmentation procedures. Thus, the present study replicates earlier findings that a strong-weak stress pattern provides a segmentation advantage relative to a weak-strong stress pattern, while extending this result to the lexical class of verbs.

The present study thus extends to verbs several factors that have been shown previously to affect the difficulty of segmentation for nouns: segmental onset type and stress pattern. In addition, the current study revealed the unexpected finding of a developmental lag for segmenting verbs compared to nouns. Indeed, bisyllabic verbs were not segmented before 13.5 months, contrary to 7.5 and 10.5 months for the segmentation of strong-weak and weak-strong bisyllabic nouns respectively (Jusczyk et al., 1999b).

We first considered whether the lag for verbs could have resulted from our use of a different speaker from the one used by Jusczyk et al. (1999b). That is, the speaker in the present study could have possessed a voice or general manner of speaking which made word segmentation more difficult. To test this possibility, we recorded the speaker from this study producing the weak-strong noun materials used in Jusczyk et al. (1999b). We presented these noun stimuli to 16 10.5-month-olds (mean = 314 days, range = 304 to 330 days; 9 males, 7 females). Evidence of segmentation was found, as attested by longer orientation times to the passages with the familiarized weak-strong nouns ($M = 7.63$ s, $SD = 1.99$) than to those with the new nouns ($M = 6.17$, $SD = 2.67$), $t(15) = 3.2, p = .007$. This replication experiment therefore rules out speaker differences as the explanation for late verb segmentation.

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4 Although there was one strong-weak verb starting with a fricative in the present study (visits), the present study was not properly counterbalanced to allow testing for a segmentation difference between words starting with a plosive versus a fricative. The same limitation applies to previously published studies in which most target words were plosives, but in which fricative-initial words were also used in a non-counterbalanced way: feet (Jusczyk & Aslin, 1995), hamlet (strong-weak condition, Jusczyk et al., 1999b) and surprise (weak-strong condition, Jusczyk et al., 1999b).

What might then be the cause of the delay found in the present study? One possibility is that the nouns in the Jusczyk et al. (1999b) passages were preceded by more familiar words than the verbs in the passages of the present study (see Appendix 1–2). This is supported by the fact that 75% of the words preceding the nouns were listed in the CDI: Words and sentences (a parental checklist of early acquired words, see Fenson et al., 1993), contrary to 25% of the words preceding the verbs. This difference could have favored segmentation in Jusczyk et al. (1999b), as attested by computational simulations (Brent & Cartwright, 1996) and new word segmentation evidence with infants (Bortfeld, Morgan, Golinkoff, & Rathbun, 2005). Whether or not these differences in the familiarity of the words preceding nouns and verbs are specific to our stimuli or would extend to the language in general will have to be evaluated through corpus analyses of child input.

Another likely possibility given the ages of the infants tested was that certain prosodic factors whose effects on segmentation have not yet been studied in detail might have played a role in the present results and those of Jusczyk et al. (1999b). To explore this possibility, the stimuli from the present study and Jusczyk et al. (1999b) were analyzed using the ToBI (Tones and Break Indices) prosodic annotation system (Beckman & Ayers-Elam, 1997; Silverman et al., 1992). We focused on the presence or absence of prosodic phrases and pitch accents,[5] which are two factors likely to influence attention to syllables and/or perceived cohesion of consecutive syllables (for adult data: Christophe, Peperkamp, Pallier, Block, & Mehler, 2004; Cutler & Darwin, 1981; Dilley & Shattuck-Hufnagel, 1999; Ladd, 1996; Pitt & Samuel, 1990; Tyler & Warren, 1987; for infant data: Gout, Christophe, & Morgan, 2004).

The prosodic analysis revealed differences in the rates of phrasal boundaries and pitch accents for the nouns in Jusczyk et al. (1999b) versus the verbs in the present study (see Table 1). In particular, although there was no difference between nouns and verbs regarding the presence of preceding phrasal boundaries, nouns were more likely than verbs to be clearly followed by a phrasal boundary (64.5% vs. 37.5%, respectively). Moreover, although there was no difference between nouns and verbs regarding the presence of a pitch accent on their stressed syllables, nouns were more likely than verbs to be clearly preceded by a syllable bearing a pitch accent (71% vs. 35.5%, respectively). These prosodic differences might have contributed to clearer perceptual demarcation of the noun stimuli used by Jusczyk et al. (1999b), and thus easier segmentation by the infants than the verbs used in the present study. This proposal is consistent with recent evidence showing that phonological phrase boundaries induce segmentation in English-learning 10- to 13-month-olds (Gout, Christophe, & Morgan, 2004).

It therefore appears possible that pitch accent and phrasal boundary distributions could partly explain the segmentation lag seen for verbs in the present study relative to the nouns in Jusczyk et al. (1999b). An intriguing question to explore in the future is whether the prosodic differences observed in these stimuli reflect prosodic/phonological differences between nouns and verbs more generally in spoken

[5] For this analysis, a phrasal boundary was taken as being present if a given word juncture had correlates of either of the two phrasal categories in the ToBI system (i.e., intermediate and full intonational phrase boundaries).

Table 1

Results of prosodic analysis. A phrasal boundary or pitch accent was said to be present (Y) or not present (N) if both experts agreed on its presence or absence, respectively, and "possibly" present (?) in all other cases. Numbers are percentages (to the nearest percent) of the 24 tokens of each stimulus type. For phrasal boundaries, results are reported at the word juncture before (i) or after (ii) a target word; for pitch accents, results are reported for the stressed syllable of the target word (iii) or for the syllable preceding the target word (iv)

	Phrasal boundary						Pitch accent					
Stimulus type	(i) Before target			(ii) After target			(iii) On stressed σ of target			(iv) On σ before target		
	Y	N	?	Y	N	?	Y	N	?	Y	N	?
SW nouns	0	100	0	75	8	17	29	29	42	54	42	4
SW verbs	21	67	13	42	42	17	42	21	38	29	67	4
WS nouns	0	100	0	54	25	21	21	38	42	88	4	8
WS verbs	0	88	13	33	21	46	13	38	50	42	54	4

English (and possibly other languages). Indeed, a more frequent presence of phrasal boundaries after nouns is syntactically motivated (Nespor & Vogel, 1986). Moreover, evidence from a recent production study using read, syntactically-controlled materials suggests that speakers produce more intonational phrase boundaries after nouns than after verbs (Watson, Breen, & Gibson, in press; see also Black & Chiat, 2003; Kelly, 1992; Sorensen, Cooper, & Paccia, 1978, for related data showing phonological differences between these two lexical classes). A logical next step in researching the effects of prosody on segmentation will be to attempt to determine whether or not the segmentation discrepancy between nouns and verbs found here would replicate using more prosodically-controlled materials.

In sum, we have demonstrated segmentation by infants for a new lexical class, verbs, as early as 13.5 months. Moreover, we extended to verbs earlier results regarding the effects of onset type and stress pattern on the segmentation of nouns. Finally, we found a lag between the onset of verb segmentation in this study relative to the onset of noun segmentation reported in earlier work. A prosodic analysis suggested the possibility that pitch accents and phrasal boundaries might be playing a role in word segmentation. The present study thus lays some basic groundwork for the future evaluation of whether pitch accents and phrasal boundaries provide cues that may be used in word segmentation.

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Appendix 1

The policeman tickets speeding drivers. Meanwhile, the clerk keeps track of how many he tickets. The meter maid tickets people who park illegally. However, diplomats' cars are not ones that she tickets. The new guard tickets trucks blocking the door. A friendly baggage clerk tickets the suitcases.

The queen visits Canada quite frequently. All the towns are decorated whenever she visits. The prince visits children in the hospital. Everyone in town is happy if the king visits. My cousin visits his teachers during the summers. The young man next door never visits the neighbors.

The earth orbits the sun once a year. Astronomers know how far Neptune orbits. The comet orbits every 50 years. The scientists don't believe that a quasar orbits. A brand new satellite orbits around Saturn. A small asteroid orbits the nearest star.

A new rule outlaws smoking in the building. The congress is never sure of how much it outlaws. This old document outlaws sales on Sundays. That politician always checks on what she outlaws. No one ever outlaws the practice of good behavior. The dean outlaws cheating in the classroom.

Appendix 2

The mother often permits her son to help. Her boss permits everyone to take a day off. We know what the red thing permits. In the park, his aunt permits everyone to swing. That's something the teacher never permits. She permits only quiet games.

She discounts the peaches on Fridays. It's surprising what the store often discounts. Buying this thing discounts the price per pound. Our aunt discounts the shoes every fall. The baker never discounts the pastries. There's no telling what his boss discounts.

The company never imports by airplane. The boss imports the goods across the ocean. Wegman's often imports cheese from France. It's not the same as what your aunt imports. We'll see how much her new thing imports. She imports rice from India.

Our boss incites a lot of activity. My aunt incites the students to learn. He almost never incites the children to yell. We can't tell what reaction she incites. The teeter-totter often incites them to play. It's amazing how much commotion that thing incites.