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WORD DURATION IN EARLY CHILD SPEECH

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Word duration in early child speech was examined through a longitudinal study of a set of frequently occurring words for three subjects. These samples were controlled for phonetic form. Durations were measured from wide- and narrow-band spectrograms. Results show that for some words, but not the majority, duration decreased over time; this effect does not appear to be due to increased familiarity with individual lexical items. Generally, word duration variations within the tested time ranges can be attributed to the effect of position-in-utterance. From the time a child first combines two words into a single phrase, a nonfinal word will be produced with a shorter duration than it would have in isolated or final position in an utterance.

In the course of our study of language acquisition, we observed that a young child's first words tend to have much longer durations than later productions. An interesting question is whether this shortening occurs generally, or whether it is a more restricted process. For example, word shortening could be limited to particular sentence contexts. If the effect is sensitive to context, what factors determine when it will occur? In this study, we examined the generality of the phenomenon and considered possible reasons for it.

Word shortening is exemplified in Figure 1. Spectrograms are shown of the word *baby* spoken by one child at ages 16½ and 24½ months. The earlier token (spectrogram a) was produced in isolation and has a duration of approximately 800 msec. The later token (spectrogram b) was embedded in the phrase *Baby lie down, Mommy,* and has a duration of approximately 300 msec. The increased duration of token "a" can be accounted for by the extended steady-state vowels, prolonged closure duration between syllables, and longer voiceless period at the end of the final vowel.

If words generally do shorten across development, one possible explanation is that speech rate and motor control increase with age and practice in production. This would result in a decrease in the duration of all words. A number of developmental studies have investigated speech segment duration and variability, including Tingley and Allen (1975), Smith (1978), and Kent and Forner (1980). Tingley and Allen tested the timing control of 5-, 7-, 9-, and 11-year-old children in sentence repetition and finger tapping. In their experiment, subjects recited "Twinkle, twinkle little star, how I wonder what you are" 30 times, and several segments were measured. The variability of segment length decreased with age. Similar decreases in variability were obtained in the finger-tapping task, suggesting that all motor control improves with age.

Smith examined several temporal parameters in 2-year-olds, 4-year-olds, and adults who were asked to give 10 repetitions of various nonsense syllables. Average word duration was greatest for the 2-year-olds, with word durations [illegible]% longer than for adults. Four-year-olds had average word durations 15% greater than did adults. The same trend was seen in segment length. In addition, the youngest age group had the largest variability in word duration. Kent and Forner obtained similar

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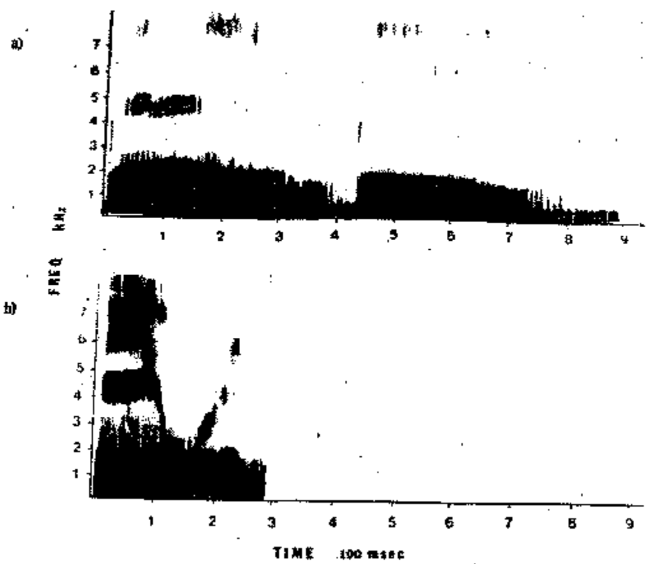

FIGURE 1. Spectrograms of the word *baby* spoken by JB. Spectrogram "a" is a token produced at age 16½ months, with a duration of approximately 800 msec. Spectrogram "b" is a token produced at age 24½ months, with a duration of approximately 300 msec.

results from groups of 4-year-olds, 6-year-olds, 12-year-olds, and adults. Subjects were asked to repeat three sentences 4 times in a random order, and the durations of various speech segments were measured. Generally, the youngest age group had the longest segment durations and the greatest variability.

A second factor that may contribute to word shortening is the child's familiarity with particular words. In a vowel duration study in which three adult speakers read from selected material, Umeda (1975) determined that unusual, unexpected words have longer durations than more frequent, anticipated words. As the speakers repeated an unpredictable word, the vowel duration was reduced. The same effect could be occurring in children's speech—new vocabulary items may have longer durations than older, more familiar words.

A third hypothesis is that word duration in child speech, as in adult speech, is partly determined by the word's position in a sentence. When two or more words are produced in an utterance, the last word will be longer than the others, but probably no longer than it would be in isolation. Nonfinal words will be shortened relative to their duration in final position or isolation. An older child's words may be shorter partly because most of the words are in nonfinal position. This may be complicated by factors such as phonetic environment, syntactic structure, stress, and affect.

Several studies have investigated the effects of position-in-utterance on word duration. In a review of these studies and other relevant literature, Klatt (1976) examined the factors affecting segmental duration in adult speakers of English. Klatt noted that increased durations are found in the syllable(s) in utterance-final position and before a pause. Greater syllable length was due primarily to increased vowel duration and longer postvocalic fricatives and sonorants. Lengthening also occurs at word, phrase, and clause boundaries, in that order of magnitude. It was suggested that duration serves as a primary cue in sentence decoding.

In addition to investigations with adult speakers, developmental studies of prepausal lengthening have been reported. Oller and Smith (1977) investigated reduplicated babbling sequences in infants and compared them with adult productions of such sequences. Prepausal lengthening was evident in the adults' utterances, but the infants did not demonstrate this effect as strongly. In fact, some infants produced longer nonfinal vowels. Oller and Smith concluded that the extended prepausal lengthening found in English is learned at some point in language development.

Looking at the late one-word stage of acquisition, Branigan (1979) investigated word duration in single word, successive single-word, and multiple-word utterances. Durations were measured from the recorded spontaneous speech of three children. Syllable type (CV structure) was controlled. Branigan found that, generally, isolated single words were longer than nonfinal words in successive single-word utterances, which in turn were longer than nonfinal words in multiple-word utterances. All comparisons were made between isolated and nonfinal words; durations of utterance-final words were not reported. These measurements are needed to determine whether all words in a multiple word utterance were shortened or whether only nonfinal words were compressed. In Smith's experiment involving nonsense-syllable repetition, tested on groups of 2-year-olds, 4-year-olds, and adults with the effects of stress controlled, all age groups produced final-syllable lengthening. There were few significant differences in both relative and absolute duration between groups.

In another study, Hawkins and Allen (1978) measured syllable duration, fundamental frequency, and amplitude as a function of word stress, sentence stress, and position-in-utterance. Their samples were taken from the spontaneous speech of six 3-year-olds. It is known that adults mark stress by increasing fundamental frequency, amplitude, and duration, and use these three cues in both final and nonfinal positions in an utterance (Lieberman, 1960). From their data, Hawkins and Allen concluded that a young child marks word and sentence stress by duration in utterance-final position but by pitch in nonfinal position. The child makes a special connection between utterance-final position and a duration increase.

These developmental studies appear to reflect various stages in the acquisition of duration differences. In the babbling period studied by Oller and Smith, the children showed only a slight effect of utterance position on syllable duration. In studying the early stages of word combination, Branigan found duration differences between isolated and nonfinal words. Smith noted final-syllable lengthening in a slightly older age group, and Hawkins and Allen reported that in later, fluent speech, children have a complex duration system tied to stress and utterance position. These studies indicate that duration differences begin to emerge sometime after the babbling period and are established within a relatively short period.

The aim of this study was to investigate further the patterns of word duration in child speech. A set of words, controlled for phonetic form, was examined for longitudinal changes in duration. We considered whether word duration decreases over time, and if so, whether part of the decrease can be attributed to word familiarity or position-in-utterance.

METHOD

Subjects

The three subjects (JB, GR, and LS) were children of educated middle-class parents. Two subjects were male (GR and LS) and one was female (JB). The subjects were taped biweekly over a time period ranging from 2 to 5 years. For this study, the data for JB's corpus range from age 66 weeks (MLU = 1.1) to 145 weeks (MLU = 4.3). The corpus for speaker GR covers age 69 weeks (MLU = 1.3) to 128 weeks (MLU = 4.6), and LS's corpus ranges from 121 weeks (MLU = 1.7) to 153 weeks (MLU = 2.8).

Equipment

The recordings were made on Scotch 1.5 mil low-noise tape with a Nagra 4.2 reel-to-reel tape recorder and an AKG directional microphone, or a Sony TC-800 reel-to-reel tape recorder and a Sony ECM 50PS electret condenser microphone. Spectrograms of speech samples were made on a Kay Elemetrics 6061B Sonograph, with a TEAC 2300S or 2300SX tape recorder providing the input.

Procedure

Subjects were tape-recorded for 45 minutes approximately every 2 weeks. The taping sessions were conducted while the children were playing at home with at least one parent present. The speech samples consisted of the child's spontaneous conversations with the parent(s) and/or experimenter. No effort was made to teach the children specific words or phrases.

Orthographic transcriptions were made of the tapes, and the words which occurred with the greatest frequency were identified for each subject. Phonetic transcriptions were then made of each token of these words; we confined further analysis to those tokens which matched the phonetic form used most often over time. Table 1 lists the words taken for each subject with their representative phonetic forms, the subjects' ages in the months which were sampled, and the number of tokens analyzed.

Phonetic variants with continuants, affricates, or no consonants at all instead of stops, or glides between vowels that were not adjacent in the vowel space, were excluded from the analysis to ensure phonetic standardization. For example, one of the most frequent words in JB's corpus was *kitty*. In the early taping sessions, the most common phonetic form for this word was [kʰii̯]. Only tokens with this syllable structure were included in the sample. Tokens of *kitty* which did not correspond to this form (such as [hi], without an initial stop) were excluded. In later sessions, JB often changed the phonetic structure of the word by adding an extra syllable, producing [kʰɪɾi]. However, tokens of [kʰii̯] were also produced, and only these tokens were analyzed. The representative phonetic form was maintained for both early and late samples.

In addition to excluding phonetic variants from the samples, no tokens were extracted from words with inflectional endings, such as pluralized nouns. Whispered, "sing-song," and laughing utterances were also excluded from the samples, as were tokens with excessive background noise or voice overlap which made measurement difficult.

Those words included in the data base were divided into three position-in-utterance categories: isolated, utterance-nonfinal, and utterance-final. Decisions about utterance boundaries were based on breath group information: Because a directional microphone was held within .6 meters of the child's mouth during the taping sessions, inhalation and exhalation were audible. The end of a breath group, marked by a breath intake, was taken to be the end of an utterance.

TABLE 1. Speech samples taken at 2-week intervals and number of tokens analyzed for subjects JB, GR, and LS.

Target word	*Representative phonetic forms*	*Age when sampled (months)*	*Tokens*
Speaker JB			
baby	bibii̯	15-28	81
boy	bɔɪ̯	17½-28	40
cat	kʰæ t	16½-28	37
cow	kʰaʊ	19-33½	28
doggie	gɔgii̯	16½-28	62
girl	gɚL	22-33	15
good	gʊ	15-33	16
kitty	kʰii̯	16½-28	25
piggie	pʰɪgii̯	24½-25½	9
see	sii̯	21½-33½	21
shoe	šuu̯	15-32½	32
Speaker GR			
big	bɪg	19½-25½	32
book	bʊk	16-29½	58
daddy	dædii̯	16-21½	22
fish	fɪš	16-29½	22
mommy	mamii̯	16-29½	65
see	sii̯	16-29½	16
tape	tʰeʔp	16½-29½	32
two	tʰuu̯	18½-25½	41
Speaker LS			
Ben	bɛn	28-35	27

Both narrow-band (90 Hz) and wide-band (600 Hz) spectrograms were made of every token in the data base. Durations were measured to the nearest 1/16 inch (1.59 mm) on the spectrogram and converted to milliseconds (1/16 in. = 6 msec). The criteria for measuring word boundaries were dependent upon the particular phonetic structure of the word. The onset of tokens with an initial stop was defined by the burst release. Pre-voicing was not included in this measurement because of the difficulty in segmenting pre-voicing from preceding vowel periodicity in utterances where the token was not in initial position. In fricative-initial items, the start of the word was determined to be the first point of high-frequency spectral energy. The beginning of those tokens with the initial nasal [m] was taken at the start of the nasal murmur, where additional formants and a mid-spectrum zero appear. The end of each word was determined to be the point at which visible energy at the first formant ended. This included word-final vocal fry register pulses, voiceless vowels, aspiration, and low-amplitude phonation.

A preliminary consideration in this study was the effect of discourse context on the child's word durations. A child's immediate repetitions of adult tokens might have adult-like durations and would not be representative of the child's own output. It might also be that the child's immediate repetitions of its own utterances would be shorter than the originals if the child benefits from immediate practice of the word. To determine whether any utterance type could be validly included in the samples, we compared four utterance types of isolated tokens of the word *cat* for JB at age 17 months, using a Kruskal-Wallis analysis of variance by ranks. For this particular test only, [kæh] served as the representative phonetic form because there were sufficient tokens with this phonetic structure for each utterance type. There were no significant differences in duration between spontaneous tokens, self-repetitions, repetitions after adults, and prompted responses to adult questions, with no apparent trends in the data. Therefore, all utterance types are included in the samples used for this study.

To summarize, our measurements derive from a large corpus of the spontaneous speech of three children. The modal phonetic forms for each child's most frequent words were identified. Word durations were measured from spectrograms of tokens which matched this form. Tokens from all utterance types are included in the samples.

RESULTS AND DISCUSSION

Nonparametric statistical tests were used to analyze the data because the duration distributions were not expected to conform to a normal distribution and because comparisons were made for each subject individually. The first question addressed was whether the words shortened over time. "Early" and "late" samples were determined for each word; the mean week of the late group was at least 5 months later than that of the early group. Table 2 lists these samples with duration ranges and medians.

The early and late samples for each word in this condition were compared for changes in duration using the Wilcoxon rank sum test. For speaker JB, three words showed a significant decrease in duration between early and late tokens: *baby* ($z = 3.31, p < .01$), *boy* ($z = 4.26, p < .01$), and *good* ($W = 37, p < .05$). Nonsignificant differences were found for the remaining seven words: *cat, cow, doggie, girl, kitty, see,* and *shoe.* Four of GR's words showed a significant decrease in duration over time: *big* ($z = 3.88, p < .01$), *book* ($z = 4.24, p < .01$), *fish* ($z = 2.31, p < .05$), and *tape* ($z = 4.22$), $p < .01$). Three words—*daddy, mommy,* and *see*—did not show a significant decrease in duration over time, and one word *two* had a significant increase in duration over time ($z = 2.65, p < .01$). The word *Ben* for speaker LS also showed a significant increase in duration as a function of age ($z = 3.01, p < .01$).

These results indicate that although some words showed significant decreases in duration over time, most did not. In fact, the average duration of two words increased over time, whereas previous research established that word duration decreases with age. Two possible reasons why conflicting results were found are: (a) the time ranges of the late samples did not extend far enough; and (b) another factor, such as position-in-utterance, affected word duration.

When position-in-utterance was controlled, there were few significant differences in duration between early and late samples. Twelve comparisons could be made using the Wilcoxon rank sum test. Late samples were significantly shorter for nonfinal tokens of JB's *good* ($W = 37, p < .05$), GR's *big* ($W = 38.5, p < .01$), and utterance-final tokens of JB's *cat* ($W = 23, p < .01$). In contrast, early samples were significantly shorter for nonfinal tokens of GR's *two* ($z = 2.43, p < .05$) and LS's *Ben* ($W = 15, p < .01$). Nonsignificant differences were found for isolated tokens of JB's *cat* and *doggie;* nonfinal tokens of JB's *baby, kitty,* and *see;* and utterance-final tokens of JB's *baby* and GR's *book.*

The durations of some of these samples were also affected by emphatic stress on selected tokens. For example, early tokens of GR's *big* were given noticeably heavy stress, which increased the average duration of these tokens. Generally, these results indicate that word duration did not decrease within the time ranges tested.

A second hypothesis—that duration is affected by the child's familiarity with a particular word—predicts that a new word will have a longer duration than a phonetically similar old word. Otherwise, all phonetically similar words should have the same average duration. To test this hypothesis, two relatively recent vocabulary acquisitions for JB were compared with two phonetically similar words which had appeared earlier and were well-established in the child's vocabulary. The new word *piggy* [pʰɪgiį] was compared to the old word *baby* [bibiį] at approximately 25 months, controlling for position-in-utterance. Similarly, the new word *cow* [kʰaʊ] was compared to the old word *boy* [bɔɪį] at approximately 20

TABLE 2. Early and late speech samples compared for number and for duration range and median (both in msec) for subjects JB, GR, and LS.

Target word	*Early sample*			*Late sample*		
	Time span (weeks)	*N*	*Duration range, median*	*Time span (weeks)*	*N*	*Duration range, median*
Speaker JB						
baby	66-85	38	325-1500 672	88-122	43	263-1169 494
boy	76-91	28	275-1081 594	109-122	12	206-513 372
cat	73-88	22	219-813 503.5	91-122	15	263-694 425
cow	81-111	20	156-956 478	113-145	8	256-1031 406.5
doggie	71-88	44	388-956 603	91-113	18	388-813 528
girl	96-122	7	413-663 494	124-143	8	288-681 469
good	66-106	7	125-781 346	109-143	9	144-256 188
kitty	71-88	14	128-1119 438	91-113	11	206-594 263
see	94	10	75-275 187.5	143-145	11	119-738 247
shoe	66-88	24	363-1350 828	124-141	8	444-1063 803
Speaker GR						
big	82-85	14	216-924 475	109-111	18	126-684 200.5
book	69-74	47	408-936 542.5	117-128	11	162-582 242.5
daddy	69-71	16	456-1176 555	88-94	6	438-1074 644
fish	69	12	486-930 648	117-128	10	204-756 360
mommy	69-71	11	330-1026 552	117-128	51	366-1008 626.5
see	88-90	6	228-648 309	123-128	10	156-474 219
tape	71-76	8	378-810 576	119-128	24	192-372 274
two	80	12	144-1026 207	109-111	29	162-810 294
Speaker LS						
Ben	121-126	17	306-990 366	151-153	10	384-744 552

months. A Wilcoxon rank sum test was used for each comparison. No results were significant, suggesting that familiarity has little effect on duration in child speech. However, more data are needed to determine fully the effect of familiarity on word duration. Differences in duration due to word familiarity probably develop as children grow older and attain more adult-like motor control.

A third hypothesis is that position-in-utterance has an effect on word duration for children as well as adults. Generally, prepausal words will be longer than nonprepausal words. The three position categories considered in this study were isolated, nonfinal, and utterance-final. Three words—JB's *baby*, *boy*, and *cat*—contained a suitable number of tokens in all positions. The Kruskal-Wallis analysis of variance by ranks was used to test for position effects in each word. Significant differences between word durations as a function of position were found for all three samples: *baby* ($H = 12.40$, $df = 2$, $p < .01$), *boy* ($H = 7.21$, $df = 2$, $p < .05$), and *cat* ($H = 20.40$, $df = 2$, $p < .001$). These results indicate that, at least for speaker JB, there is a general position effect on duration.

In addition to these tests, individual position comparisons were made with Wilcoxon rank sum tests for all words wherever possible, combining early and late samples.

Isolated versus Nonfinal Durations

When isolated and nonfinal tokens were compared, significant differences in duration were found for 10 of the 13 words tested. Nonfinal tokens were significantly shorter than isolated tokens for JB's *baby* ($z = 5.67$, $p < .01$), *boy* ($W = 52.5$, $p < .01$), *cat* ($z = 2.54$, $p < .05$), *cow* ($z = 2.85$, $p < .01$), and *kitty* ($W = 43.5$, $p < .01$), and for GR's *big* ($W = 36$, $p < .01$), *book* ($W = 21$, $p < .01$), *see* ($W = 19$, $p < 02$), *tape* ($z = 4.09$, $p < .01$), and *two* ($z = 4.27$, $p < .01$).

However, three samples showed no significant differences in duration between isolated and nonfinal tokens: JB's *shoe*, GR's *mommy*, and LS's *Ben*.

Nonfinal versus Utterance-Final Token Durations

In another test, nonfinal tokens were compared with utterance-final tokens for JB's *boy, cat, baby*, and *shoe;* GR's *book* and *mommy;* and LS's *Ben*. Nonfinal tokens had significantly shorter durations in 4 of the 7 words tested: *boy* ($W = 43$, $p < .05$), *baby* ($z = 5.29$, $p < .01$), *book* ($z = 3.58$, $p < .01$), and *Ben* ($W = 34.5$, $p < .05$). No significant differences in duration were found between nonfinal and utterance-final tokens of *cat, shoe*, and *mommy*.

Isolated versus Utterance-Final Token Durations

To see whether there were any differences between the two prepausal conditions, isolated and utterance-final tokens were compared for nine words. No significant differences in duration were found for JB's *baby, boy*, and *doggie*, and for GR's *fish* and *mommy*. Isolated tokens had significantly longer durations for three words: JB's *shoe* ($W = 60.5$, $p < .05$) and *cat* ($z = 2.18$, $p < .05$), and GR's *book* ($z = 3.06$, $p < .01$). Utterance-final tokens were significantly longer for one word, LS's *Ben* ($W = 30$, $p < .05$).

These tests of position-in-utterance effects across early and late samples indicate that, generally, tokens in a nonfinal position are shorter than either isolated or utterance-final tokens. Also, there is often no difference between isolated and utterance-final tokens. The major influence appears to be whether a word is followed by a pause or not.

The results can be summarized as follows: (a) for some but not the majority of words studied, duration decreased over time; (b) decreases do not appear to be due to increased familiarity with individual lexical items; and (c) word duration variations within the tested time ranges appear to be largely attributable to the effect of position-in-utterance. Isolated and utterance-final tokens of a word are longer than nonfinal tokens (see Figure 2).

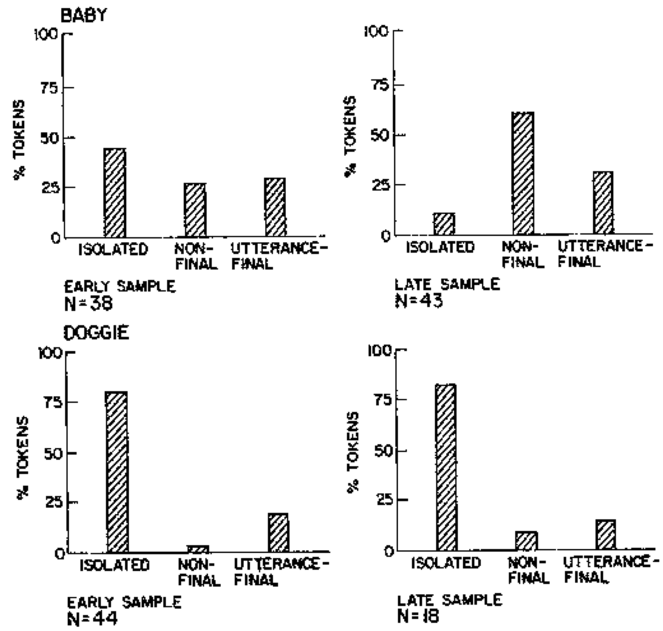

FIGURE 2. Distributions of isolated, nonfinal, and utterance-final tokens for JB's *baby* and *doggie*. The upper histograms show early and late distributions for *baby*, a word whose duration decreased over time. The lower histograms give the early and late distributions for *doggie*, a word whose duration did not decrease over time.

The upper histograms show the percentage of isolated, nonfinal, and utterance-final tokens in the early and late samples of JB's *baby*. The duration of this word decreased over time. The lower histograms give the same information for JB's *doggie*, a word for which duration did not decrease with age.

The upper sample exemplifies the change in token distribution which occurred in 6 of the 7 words whose durations decreased over time. There was a 40% minimum increase in the proportion of nonfinal tokens in the late samples of these words. In contrast, 7 of the 10 words for which duration did not decrease over time had approximately the same distributions in both early and late samples; an example is illustrated in the lower histograms.

A few results conflicted with the position-in-utterance hypothesis. These included samples in which nonfinal tokens were either not shorter than isolated tokens or not shorter than utterance-final tokens. In most of these cases, affect and stress were confounding factors. We are confident that larger samples would limit the influence of arbitrary prosodic factors in the analysis.

In conclusion, the most interesting result of this study is that from the time a child first combines two words into a single phrase, a nonfinal word will be produced with a shorter duration than it would have in isolated or final position in an utterance. Average word duration may decrease as a child grows older partly because a larger percentage of tokens appears in nonfinal position.

Several directions for future research are suggested by this study. One is the interaction of utterance-internal shortening and syntactic structure. Cooper (1976) claimed that a clause or phrase-final word will be lengthened even if no pause occurs with the syntactic boundary and that the degree of lengthening will correlate with the strength of the boundary. Our corpus of spontaneous child speech does not permit systematic duration comparisons between various syntactic constructions. Longitudinal data of this sort could be obtained with a different experimental design. This would provide some information on how children plan speech production.

A second research direction would be to investigate segment duration in different syntactic structures. The effect of sentence context and speech rate on segment length would be particularly interesting in terms of developmental speech production. These data would provide insight into how children plan and execute motor control programs and whether the basic production unit changes with age.

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