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**Effects of Alcohol on the Production of  
Words in Context: A First Report<sup>1</sup>**

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## Effects of Alcohol on the Production of Words in Context: A First Report

**Abstract.** This study examined the effects of alcohol on acoustic parameters of spoken words in sentential contexts. Nine male talkers recorded 66 isolated sentences in a shadowing task in both a nonalcohol (BAC = 0.00%) and an alcohol condition (BAC  $\geq$  0.10%). From these sentences, 79 keywords were isolated and analyzed in terms of duration, fundamental frequency, probability of voicing, RMS amplitude, and AC peak. All talkers exhibited an increase in mean word duration; this increase was significant across talkers as well as for seven of the individual talkers. There was no significant difference in mean fundamental frequency, but the variability of fundamental frequency increased significantly from the nonalcohol to the alcohol condition. No significant differences were found between conditions in probability of voicing and AC peak. However, RMS amplitude increased significantly from the nonalcohol to the alcohol condition. These results are consistent with previous findings regarding the effects of alcohol on acoustic-phonetic parameters of speech.

### Introduction

It is a commonplace observation that, among the various effects of alcohol consumption, the ability to produce speech is affected. Although superficial awareness of alcohol's effect on speech is millennia-old, the scientific study of these effects is not much older than this century (see Chin & Pisoni, 1997). During the twentieth century, the effects of alcohol on speech have been examined from a number of different perspectives, including medicine, psychology, and speech science.

Before the application of instrumental acoustic analysis to the investigation of alcohol effects on speech, research on this topic was generally conducted by medical and psychological investigators, and methodologies were generally derived from these disciplines. Especially insofar as speech is viewed as a behavior, early twentieth-century research drew on the expanding field of experimental psychology. Dodge and Benedict (1915), for instance, investigated voice reaction times to visual stimuli both with and without a standard dose of alcohol. Hollingworth (1923) measured the total time necessary for subjects to say aloud the names of colors of printed squares. Forney and Hughes (1961) were among the first to examine specifically the nature of speech produced under alcohol; they found that speech errors of various types (e.g., omissions, mispronunciations) did not increase significantly after alcohol consumption. Analysis of speech errors was a common methodology employed after Forney and Hughes (1961). Trojan and Kryspin-Exner (1968) observed increases in both syntactic and phonetic errors after consumption of alcohol, as well as changes in voice quality. In a study of Bulgarian-speaking talkers, Zaimov (1969) found that various types of errors (e.g., substitutions, omissions, repetitions) at various linguistic levels (e.g., word, syllable) increased as a function of increased alcohol consumption. Sobell and Sobell (1972) likewise found that errors committed while reading aloud a standard passage increased after alcohol consumption.

Alcohol's depressant effects on the central nervous system are manifested at both the cognitive and the motoric levels of functioning, although changes in speech production have most often been viewed as decrements in motor control. Furthermore, the changes that occur have for the most part been investigated from an analysis of the radiated speech signal, either acoustically or auditorally. A few researchers, however, have conducted more direct examinations of morphological or physiological changes in the organs of speech production that occur after consumption of alcohol. Investigation in this area has generally

concentrated on the vocal folds. Dunker and Schlosshauer (1964) examined hoarseness in 46 German-speaking subjects using high-speed photography and stroboscopy. One of the subjects was instructed to "yell and sing with full voice when celebrating and consuming alcoholic beverages liberally" (p. 165). Although the effects of alcohol were most likely confounded with those of overusing the voice, Dunker and Schlosshauer concluded in any case that any effects were minimal. More recently, Künzel, Braun, and Eysholdt (1992) performed endoscopic and stroboscopic examination of the vocal folds. No morphological changes (specifically edema) were observed, although changes in vocal fold function were found: decreased vibration amplitude, reduced mucosal waves, and insufficient vocal fold adduction. Along with changes in fundamental frequency and intensity, Watanabe et al. (1994) also found vocal fold injections and edema on fiberoptic examination of Japanese talkers after alcohol. Whereas visual observation of the vocal folds is fairly observer-dependent and subjective, electroglottography is both a noninvasive and a relatively objective (although indirect) method of assessing laryngeal function. This method was employed by Johnson et al. (1993), who hypothesized that open quotient (i.e., the ratio of the glottal open phase to the entire glottal wave cycle) would decrease if there were morphological changes in the vocal folds (e.g., edema, swelling) resulting from alcohol consumption. In fact, they found that open quotient tended to increase as a function of rising blood-alcohol concentration (BAC).

Instrumental acoustic analysis of alcohol effects on speech is a relatively recent development, dating back only to the mid 1970s. From spectrographic analysis, Lester and Skousen (1974) found that sound substitutions and both consonant and vowel lengthening occurred in speech produced under alcohol. Fontan, Bouanna, Piquet, and Wgeux (1978) noted vowel formant compacting, vowel lengthening, voicing, frication, vocalization, and aspiration in the (French) speech of acutely alcoholized alcoholic subjects. Klingholz, Penning, and Liebhardt (1988), in a study of German-speaking talkers, found that frequency distributions of fundamental frequency, signal-to-noise ratio, and long-term average spectrum could discriminate speech produced with and without alcohol with a less than 5% error rate.

In a large-scale, comprehensive study of alcohol effects on the (German) speech of 33 acutely alcoholized subjects, Künzel, Braun, and Eysholdt (1992) found that alcohol brought about changes in nasality, segmental lengthening, incomplete articulations, changes in fundamental frequency, slowing in speaking rate, and increases in the number and duration of pauses. In a study of voice onset time (VOT), Swartz (1992) found that VOT variability appeared to be resistant to the influence of alcohol. Hollien and Martin (1996) reported that fundamental frequency increased for most of their subjects, and passage durations tended to increase, both as functions of increments in intoxication. Cummings, Chin, and Pisoni (1996) reported that pitch and intensity measures revealed no significant differences between speech produced with and without alcohol, but that jitter (frequency perturbation) and shimmer (amplitude perturbation) increased under alcohol. Additionally, using a glottal inverse filtering procedure to derive glottal excitation waveforms, Cummings et al. demonstrated that the glottal waveshape is less consistent and the vocal tract less stationary under alcohol.

The database used in the present study has been subjected to a number of analyses. Initially, Pisoni, Yuchtman, and Hathaway (1986) performed several perceptual, transcription, and acoustic analyses of speech data from four talkers. Perceptual results showed that both experienced (laboratory staff) and naive (college undergraduate) listeners could reliably discriminate sentences spoken with and without alcohol. Phonetic transcription by trained listeners revealed various types of errors in speech produced under alcohol, including vowel lengthening, deletions, partial articulations, and deaffrication. Acoustic analysis revealed, among other things, reliable changes in durational and timing aspects of speech produced under alcohol. Pisoni and Martin (1989) reiterated the perceptual findings of Pisoni et al. (1986), using Indiana State Police officers as listeners. Behne and Rivera (1990) examined alcohol effects on both

segmental and prosodic properties of spondees. They found that, under alcohol, speech was produced with lower second and third formants, increased amplitude and amplitude variability, and increased fundamental frequency and fundamental frequency variability. Behne, Rivera, and Pisoni (1991) examined durational effects of alcohol in isolated words, sentences, and passages. They found that although isolated sentences and sentences within passages were reliably longer under alcohol, the durations of isolated monosyllabic and spondaic words were not reliably different between alcohol and nonalcohol conditions

In the present study, we examined the effects of alcohol on various acoustic parameters of single words in sentential contexts.

## Method

The study of words in context reported here was part of a larger study conducted at the Speech Research Laboratory at Indiana University Bloomington under contract with General Motors Research Laboratories (Warren, MI).

### Subjects

Subjects for this study were nine male volunteers at Indiana University between 21 and 26 years old who were recruited through a newspaper advertisement. They were paid to serve as subjects. All were native speakers of English, and none had a history of speech, hearing, or language disorder. All subjects completed a set of questionnaires to assess alcohol consumption and risk for alcoholism: (1) the short Michigan Alcoholism Screening Test (Selzer, Vinokur, & Van Rooijen, 1975), (2) the MacAndrew Scale (MacAndrew, 1965), (3) the socialization subscale of the California Psychological Inventory (Gough, 1969), and (4) a short alcohol-consumption questionnaire. Only subjects shown by these assessments to be moderate social drinkers at low risk for alcoholism were included in the study. Table 1 shows demographic data and screening test scores for the nine subjects.

### Speech Samples

Subjects provided the following types of speech samples for analysis: 204 isolated monosyllabic words, 38 isolated spondaic words, 66 isolated simple sentences, 15 isolated alliterative sentences, and 3 connected passages. Monosyllabic words and the isolated simple sentences were presented auditorally in a shadowing task. The spondaic words and alliterative sentences were stored in digital files on a PDP 11/34 computer for visual presentation on a CRT video screen during recording. The three passages were typed separately on white paper for reading. The auditory stimuli (204 monosyllabic words, 66 simple sentences) were prerecorded in citation form by a male talker in a sound-attenuated booth using an Electro-Voice (Model D054) microphone and an Ampex AG-500 tape recorder. Stimuli were then low-pass filtered at 4.8 kHz and digitized at a 10 kHz sampling rate through a 12-bit A/D converter. A digital waveform editor (Luce & Carrell, 1981) was used in conjunction with a PDP 11/34 computer to edit the speech stimuli into separate digital files for later playback. Four audio tapes were produced using a computer-controlled audio tape-making program. The digital waveforms were output through a 12-bit D/A converter, low-pass filtered at 4.8 kHz and recorded on audio tape at a speech of 7.5 ips. On two of the audiotapes, the monosyllabic words were recorded first, with one second of silence after each word. The simple sentences were then recorded with three seconds of silence after each sentence. A different random ordering of words and sentences was used for each tape. The remaining two tapes were constructed similarly, but the sentences preceded the monosyllabic words.

**Table 1: Subject Characteristics**

Subject	Age	Initial BAC <sup>a</sup>	Final BAC <sup>b</sup>	MAST <sup>c</sup>	SOC <sup>d</sup>	MAC <sup>e</sup>	Alcohol intake, prior 30 days <sup>f</sup>
1	26	.10%	.10%	2	35	22	6.15
2	22	.16%	.10%	3	39	23	3.53
3	21	.17%	.10%	5	30	27	16.80
4	21	.13%	.075%	4	29	20	5.15
5	22	.15%	.085%	5	31	27	23.20
6	25	.135%	.15%	7	33	18	26.99
7	21	.15%	.10%	6	36	24	8.94
8	21	.15%	.095%	0	42	22	13.13
9	21	.19%	.12%	6	34	27	5.54

<sup>a</sup>Blood-alcohol concentration at beginning of recording session; <sup>b</sup>Blood alcohol concentration at end of recording session; <sup>c</sup>Short Michigan Alcoholism Screening Test (Selzer, Vinokur, & Van Rooijen, 1975); <sup>d</sup> Socialization subscale of California Psychological Inventory (Gough, 1969); <sup>e</sup>MacAndrew Scale (MacAndrew, 1965); <sup>f</sup>Self-reported alcohol intake during 30 days prior to experimental session (converted to fluid ounces 200-proof alcohol).

Speech materials for the study reported here consisted of the 66 isolated simple sentences, taken from Borden (1971), each containing one or two "keywords" on which acoustic measurements were made. The keywords from 34 of the sentences had been analyzed previously by Borden (Borden, 1971; Borden, Harris, & Oliver, 1973; Borden, Harris, & Catena, 1973) in studies of the effects of oral anesthesia (2% lidocaine) on speech; in addition, segmental and sentential acoustic analyses of these 38 keywords and 34 sentences had been performed by Pisoni, Yuchtman, and Hathaway (1986) in their study of alcohol effects on speech. One or two keywords from each of the remaining 32 sentences were selected for the present study, according to criteria established in Borden (1971) for the original 38 keywords, that is, with weighting toward fricatives and consonant clusters. Forty-one keywords were thus selected from the 32 sentences, so that analyses were performed on a total of 79 keywords.

### Subject Preparation

Subjects participated in two recording sessions, one with alcohol ("alcohol") and one without ("nonalcohol"). Subjects agreed not to eat or drink for four hours prior to each experimental session. When subjects arrived for the nonalcohol session, blood-alcohol concentration (BAC) was measured from breath with a Smith & Wesson Breathalyzer (Model 900A) to insure an absence of alcohol in the system. On arrival for the alcohol session, subjects were administered a breath-alcohol test and then weighed before administration of alcohol. The alcohol preparation consisted of one part 80-proof (40%) vodka to three parts orange juice, administered in a dose of 1 gm alcohol per kg body weight, designed to raise BACs to 0.10 gm alcohol/100 ml blood (0.10%) over a 45-minute period. Subjects consumed a third of the total dose every 15 minutes. After 45 minutes, subjects rinsed their mouths and were administered a second breath-alcohol test. When BACs were at least 0.10%, audio recordings were made of subjects' speech samples.

### Procedure

During recording sessions, subjects were seated in a sound-attenuated IAC booth, wearing a pair of matched and calibrated TDH-39 headphones with a boom-attached EV C090 L0-Z condenser microphone. Microphone placement was 4 inches directly in front of the subject's mouth. Auditory stimuli for

shadowing were presented through the headphones from audiotape. Subjects were instructed to listen carefully to each stimulus sentence and then to repeat it back (i.e., to "shadow" it) aloud as soon as possible. Subjects were also informed that they would have a limited amount of time to repeat each sentence. All spoken responses were audio-recorded using a second Ampex AG-500 tape recorder. Recording levels were adjusted at the commencement of each subjects' initial recording session and, in order that amplitude could be compared across the two conditions, remained the same throughout both sessions.

All subjects remained naive to the actual purpose of the experiment. They were informed only that the experiment involved the effects of alcohol on memory and the rate at which they could shadow material after alcohol ingestion. No mention was made of the planned acoustic analyses that would be conducted, although this possibility was raised in the consent form that all subjects read and signed before the experiment began.

### Analysis

All sentences were low-pass filtered (9.6 kHz cutoff) and digitized at a rate of 20,000 samples/sec. Each digitized sentence was stored in a computer file in ILS format (Interactive Laboratory Systems: Signal Technology, Inc.). To facilitate analysis in the present study, the digitized data files were then written to CD-ROM, originally in the same ILS format. However, because analysis was to be performed with software lacking native support for the ILS format, the files were transformed to the Entropic Waves SD format (Entropic Research Laboratory, Inc.) and written to a second CD-ROM (D'Haenens & Hernández S., 1995).

The digital speech files of productions of the sentences were then analyzed from the CD on a Sun SPARCstation 5 implementing ESPS/*waves+*, a digital signal processing and interactive display and editing software package (Entropic Research Laboratory, Inc., AT&T Bell Laboratories). Using time-aligned windows for waveforms, wide-band spectrograms, and labels, the onset and offset boundaries<sup>3</sup> of all 79 keywords in the 66 sentences were marked and labeled. A label consisted of the sample number and an alphanumeric marker to identify the labeled point. The labels thus created were saved in files and could be retrieved for use in subsequent acoustic analysis of signal properties between the marked boundaries.

Automated acoustic analysis of the keywords as segmented using the labeling program was implemented with a C-shell script incorporating the "get\_f0" program, which calculated the following measures:

- a. An estimation of fundamental frequency of the sampled-data speech file using the normalized cross-correlation function and dynamic programming (Secretst & Doddington, 1983; Talkin, 1995).
- b. Probability of voicing
- c. RMS amplitude
- d. AC peak (peak amplitude of a wave above zero-current)

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<sup>3</sup> In some cases, acoustic material from the preceding or the following word was included in the keyword. This occurred, for instance, when the keyword began with a sibilant and the preceding word ended with a sibilant (e.g., "his *sweater*"). In such cases, there was often continuous friction for the two sibilants, and the word boundary was ambivalent between the two words; therefore, the onset of the keyword was marked as the commencement of the entire span of friction. In all cases such as this one, however, uniform segmenting criteria were applied across conditions and talkers.

As mentioned, the label files contained a field indicating the temporal location of each label within the entire speech file. These timing indicators were imported into Microsoft Excel, where their differences were used to determine the total duration of each of the keywords.

Differences in durations were calculated by subtracting values in the nonalcohol condition from those in the alcohol condition. Differences in all measures obtained from “get\_f0” were calculated by subtracting values in the alcohol condition from those in the nonalcohol condition. A series of paired *t* tests was performed to compare measurements from the nonalcohol and alcohol conditions, to determine effects of alcohol on words in context, for the following parameters:

- a. Duration: Mean duration
- b. Fundamental frequency (F0): Mean F0, Minimum F0, Maximum F0, Standard deviation of F0
- c. Probability of voicing: Mean probability of voicing, Standard deviation of probability of voicing
- d. RMS amplitude: Mean RMS amplitude, Maximum RMS amplitude, Standard deviation of RMS amplitude
- e. AC peak: Mean AC peak, Minimum AC peak, Maximum AC peak, Standard deviation of AC peak

## Results

### Durations

Durations of keywords ranged from 97 ms to 826 ms in the nonalcohol condition and from 178 ms to 910 ms in the alcohol condition. Mean duration across all keywords and all talkers was 466 ms (*SD* = 111) in the nonalcohol condition and 496 ms (*SD* = 116) in the alcohol condition. A paired *t* test showed the difference in mean duration between the two conditions to be highly significant ( $t = 11.376, p < .0001$ ). Figure 1 compares mean durations across keywords for each talker in the nonalcohol and alcohol conditions.

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 Insert Figure 1 about here  
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As Figure 1 indicates, all talkers exhibited increased mean durations from the nonalcohol to the alcohol condition. For all but two talkers (Talkers 3 and 5), these differences were statistically significant, as indicated in Table 2.

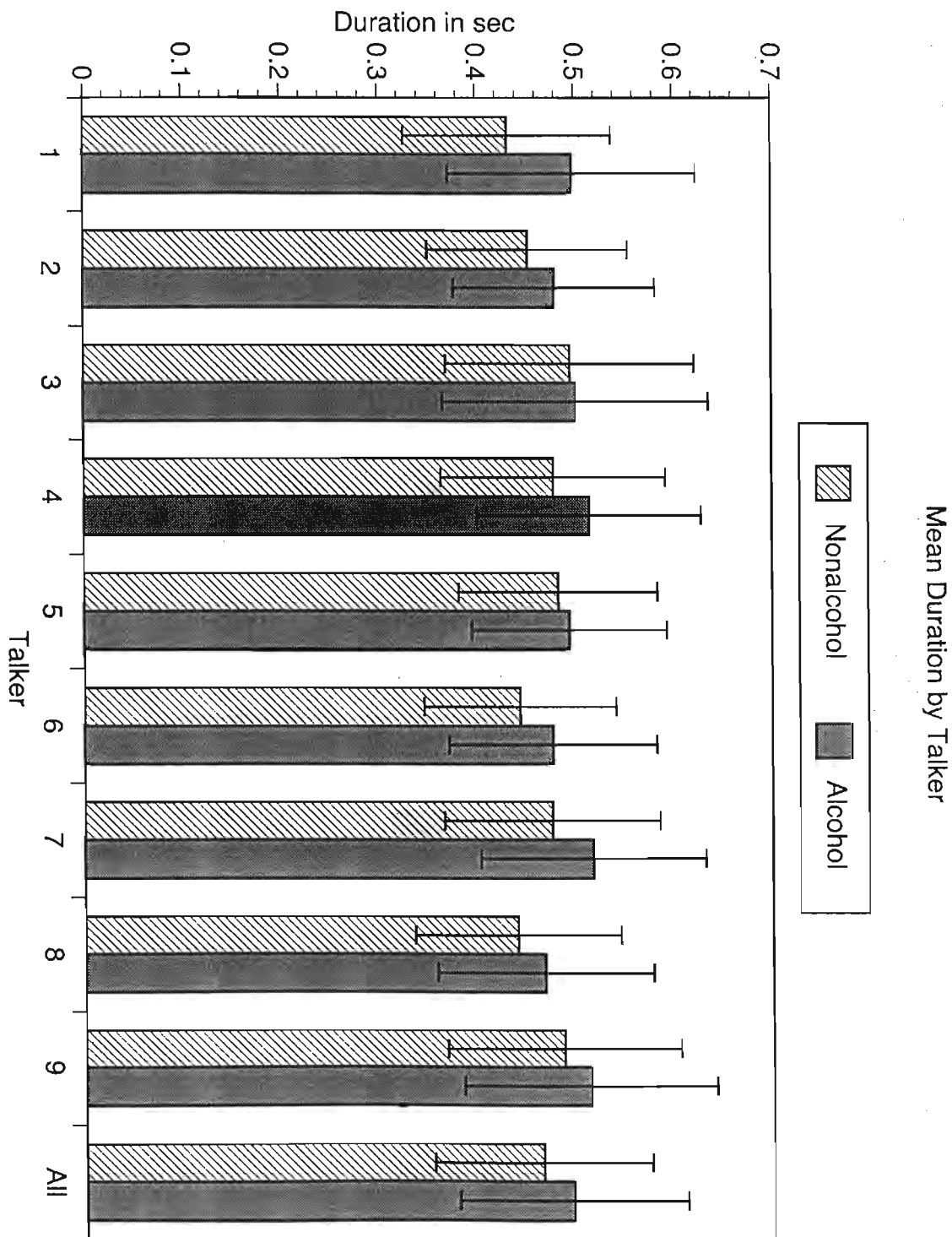


Figure 1: Mean duration (in seconds) of 79 sentence-embedded keywords by individual talker in nonalcohol (BAC = 0.00%; lighter bars) and alcohol (BAC  $\geq$  0.10%; darker bars) conditions. Error bars indicate standard deviations.

**Table 2: Duration: Paired *t* test by individual talker**

Talker	Mean Diff (ms)	DF	<i>t</i> value
1	66	78	7.978***
2	26	78	3.589**
3	8	78	.906
4	35	76	3.495**
5	10	78	1.455
6	35	78	5.073***
7	41	78	6.159***
8	28	78	3.864**
9	27	78	3.240*

\**p* < .01; \*\**p* < .001; \*\*\**p* < .0001

### Fundamental Frequency

Table 3 presents descriptive statistics for measurements of fundamental frequency in the keywords. Table 4 shows results from paired *t* tests for measurements involving fundamental frequency:

**Table 3: Fundamental Frequency (F $\emptyset$ ) Descriptive Statistics**

	Nonalcohol		Alcohol	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Mean	95.508	34.013	96.617	36.938
SD	30.241	21.045	31.794	25.191
Minimum	0.000	0.000	0.000	0.000
Maximum	219.960	114.910	279.130	218.32

**Table 4: Fundamental Frequency (F $\emptyset$ )**

	Mean Difference	<i>DF</i>	<i>t</i>
Mean F $\emptyset$	-1.129	708	-1.272
Minimum F $\emptyset$	2.833	708	2.047*
Maximum F $\emptyset$	-5.683	708	-3.105*
Standard Deviation of F $\emptyset$	-2.915	708	-3.550**

\**p* < .05; \*\**p* < .001

As Table 4 indicates, differences in minimum F $\emptyset$ , maximum F $\emptyset$ , and standard deviation of F $\emptyset$  between the nonalcohol and alcohol conditions were also statistically significant; the difference in mean F $\emptyset$  between conditions was not significant. Across all talkers, the mean change in F $\emptyset$  from the nonalcohol to

the alcohol condition was an increase of 1.13 Hz ( $t = -1.272$ ). Figure 2 shows that of the nine talkers, four (Talkers 1, 5, 6, 9) increased mean F $\emptyset$  in the alcohol condition, and five talkers (Talkers 2, 3, 4, 7, 8) decreased F $\emptyset$ . Only three of the changes were statistically significant: the decreases for Talkers 3 ( $t = 2.413, p < .05$ ) and 7 ( $t = 2.685, p < .01$ ) and the increase for Talker 5 ( $t = -3.573, p < .001$ ).

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Insert Figure 2 about here  
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Thus, for two-thirds of the talkers in this study, fundamental frequency did not change significantly under alcohol, and for individual talkers, the significant results were equivocal as to the direction of change in F $\emptyset$  after consumption of alcohol.

The change in minimum F $\emptyset$  from the nonalcohol to the alcohol condition was a mean decrease of 2.83 Hz, a marginally significant difference ( $t = 2.047, p < .05$ ). There was also a mean increase in maximum F $\emptyset$ , however, of 5.68 Hz, a significant difference ( $t = -3.105, p < .01$ ). Thus, although mean F $\emptyset$  remained unchanged, there were significant changes at both ends of the frequency range, that is, a decrease in mean minimum F $\emptyset$  and an increase in mean maximum F $\emptyset$ , which served to expand the frequency range of F $\emptyset$  by approximately 5.15 Hz.

Concomitant with expansion of the frequency range of F $\emptyset$  was an increase in the variability of F $\emptyset$ , as measured by the standard deviation. Across talkers, the mean increase in standard deviation was 2.92 Hz from the nonalcohol to the alcohol condition, a significant increase in variability ( $t = -3.550, p < .001$ ). As shown in Figure 3, across keywords, the standard deviation of F $\emptyset$  increased for six talkers (Talkers 1, 4, 5, 6, 8, 9) and decreased for three talkers (Talkers 2, 3, 7). Only two of the differences were statistically significant, both of them increases: Talker 5 ( $t = -3.445, p < .001$ ) and Talker 6 ( $t = -3.028, p < .01$ ).

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Insert Figure 3 about here  
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### Other Acoustic Measures

Mean probability of voicing (ranging from 0 to 1) was .509 ( $SD = .464$ ) in the nonalcohol condition and .504 ( $SD = .470$ ) in the alcohol condition. This difference was not significant ( $t = 1.27, p = .205$ ). Similarly, mean AC peak was .596 ( $SD = .335$ ) in the nonalcohol condition and .592 ( $SD = .336$ ) in the alcohol condition, also a nonsignificant difference ( $t = 1.422, p = .156$ ).

Across keywords, mean RMS amplitude ranged from 129.96 to 1478.48 in the nonalcohol condition and from 111.60 to 2239.83 in the alcohol condition. Mean RMS amplitude across talkers was 481.44 ( $SD = 322.05$ ) in the nonalcohol condition and 521.53 ( $SD = 359.48$ ) in the alcohol condition, a significant difference ( $t = -6.782, p < .0001$ ). Of the nine talkers in this study, seven showed increases in amplitude from the nonalcohol to the alcohol condition, and two showed decreases, as shown in Figure 4.

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Insert Figure 4 about here  
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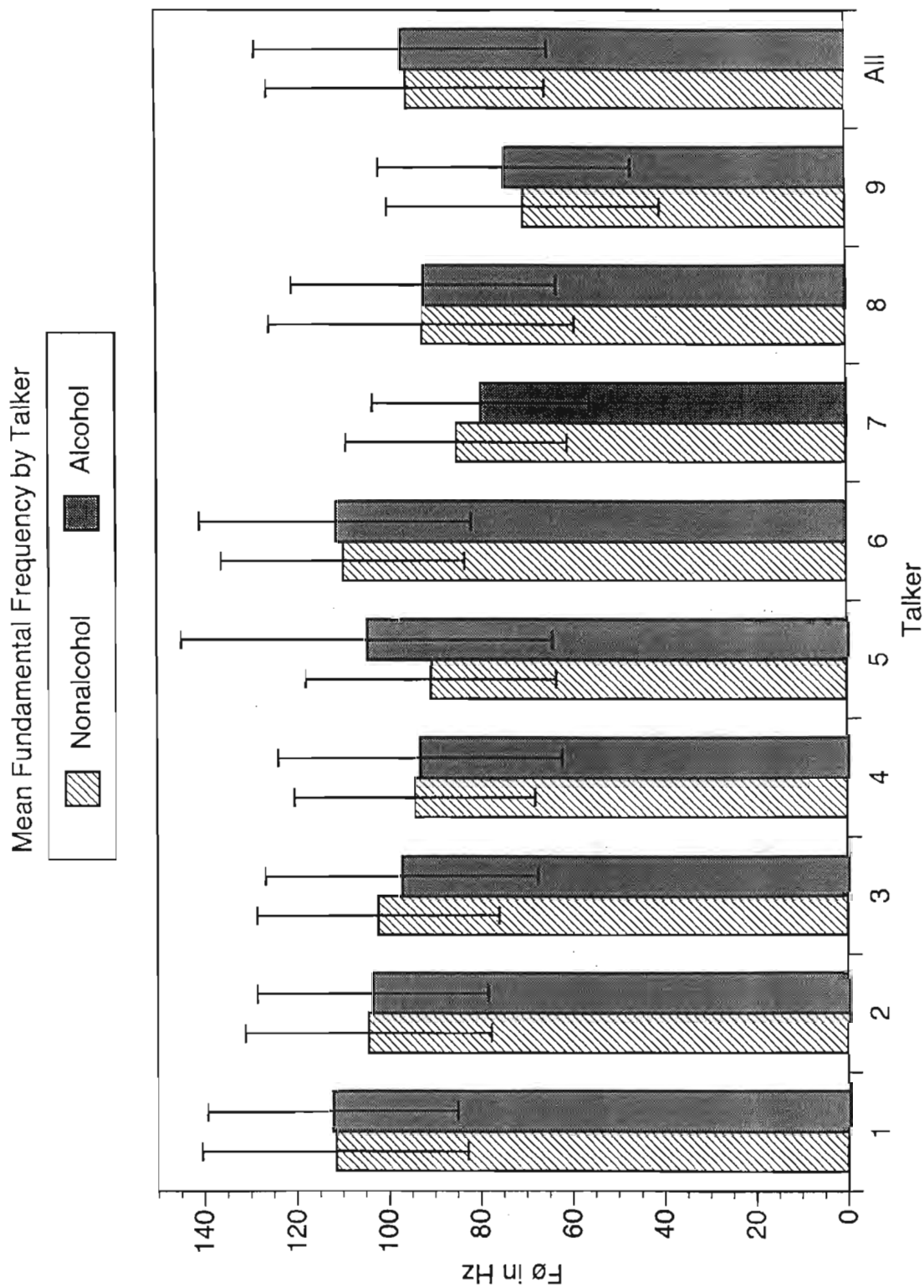
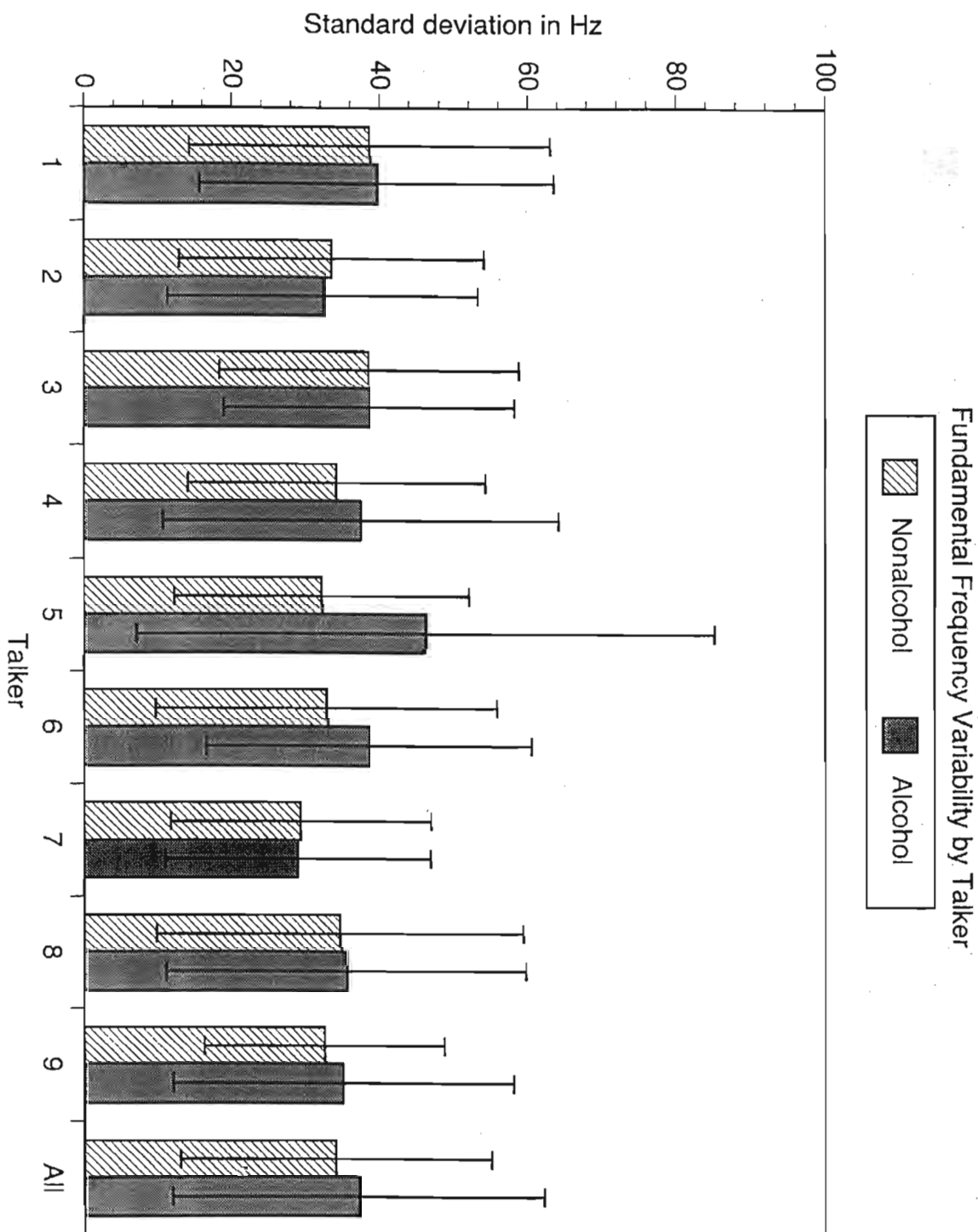


Figure 2: Mean fundamental frequency (in Hz) in 79 sentence-embedded keywords by individual talker in nonalcohol (BAC = 0.00%; lighter bars) and alcohol (BAC  $\geq$  0.10%, darker bars) conditions. Error bars indicate standard deviations.



**Figure 3:** Mean standard deviation of fundamental frequency (in Hz) in 79 sentence-embedded keywords by individual talker in nonalcohol (BAC = 0.00%; lighter bars) and alcohol (BAC  $\geq$  0.10%; darker bars) conditions. Error bars indicate standard deviations.

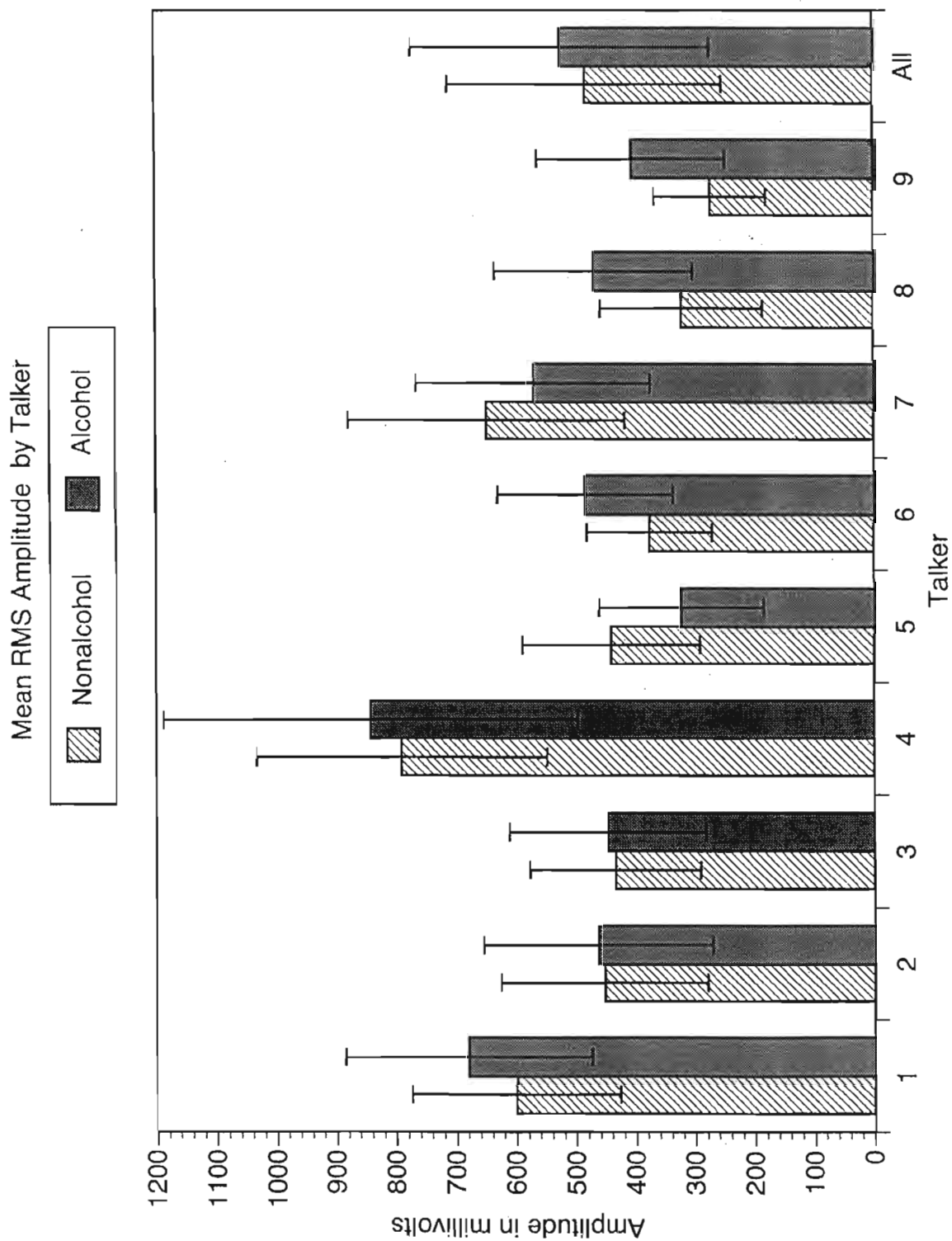


Figure 4: Mean RMS amplitude (in millivolts) in 79 sentence-embedded keywords by individual talker in nonalcohol (BAC = 0.00%, lighter bars) and alcohol (BAC ≥ 0.10%; darker bars) conditions. Error bars indicate standard deviations.

The increases in mean RMS amplitude were significant for Talkers 1, 4, 6, 8, and 9 ( $p < .01$ ) but not significant for Talkers 2 and 3. Both cases of decreases in amplitude (Talkers 5 and 7) were significant ( $p < .0001$ ). Mean maximum RMS amplitude across talkers was 1076.24 ( $SD = 481.44$ ) in the nonalcohol condition and 1221.95 ( $SD = 249.27$ ) in the alcohol condition; this increase was significant ( $t = -8.90$ ,  $p < .0001$ ).

## Discussion

This study examined the effects of alcohol on the duration, fundamental frequency, and other acoustic parameters of words produced in sentential contexts. Consistent with a large number of previous studies, the most robust effect of alcohol in this study was on duration. Mean duration of keywords in the nonalcohol condition was 466 ms, and in the alcohol condition 496 ms, a significant increase ( $p < .0001$ ). Previous studies have examined the effects of alcohol on the durations of a variety of linguistic units, including connected passages (e.g., Behne et al., 1991; DeJong, Hollien, Martin, & Alderman, 1995; Sobell et al., 1982), sentences (e.g., Behne et al., 1991; Pisoni et al. 1985), spondees (e.g., Behne et al., 1991), monosyllabic words (Behne et al., 1991), syllables (e.g., Behne & Rivera, 1990), consonants and vowels (e.g., Künzel et al., 1992; Pisoni et al., 1985, 1986), and VOT (e.g., Swartz, 1992). Across studies and across linguistic materials, durations were consistently and significantly greater under alcohol than without alcohol.

Particularly relevant in the present context is the earlier study by Behne et al. (1991). They examined duration effects of alcohol on isolated words, sentences, and passages, using the same speech materials from the same nine talkers as the present study. In the nonalcohol condition, mean durations of 34 of the sentences containing the keywords examined in the present study were 1510 ms in the nonalcohol condition and 1640 ms in the alcohol condition, a significant difference ( $F_{1,30} = 182.67$ ,  $p < .001$ ). Both monosyllabic words and spondees were also produced during the same sessions as the simple sentences. Mean durations of monosyllabic words were 521 ms in the nonalcohol condition and 540 ms in the alcohol condition, a significant increase ( $F_{1,406} = 37.08$ ,  $p < .001$ ). On the other hand, although mean durations of spondees were greater in the alcohol condition (529 ms) than in the nonalcohol condition (519 ms), this difference was not statistically significant ( $F_{1,74} = 1.50$ , n.s.).

In addition to measurements of duration, the literature on the effects of alcohol on speech also reports measures of fundamental frequency ( $F_0$ ), one of the acoustic correlates of perceived pitch. Both change in mean  $F_0$  and change in the variability of  $F_0$  have been examined. In the present study,  $F_0$  increased slightly but not significantly from the nonalcohol to the alcohol condition. Likewise, Künzel et al. (1992) reported a nonsignificant increase of 4.6 Hz. On the other hand, the increase in  $F_0$  was significant for vowels in spondees reported by Behne and Rivera (1990). Although these studies indicated a general trend toward increase in  $F_0$  under alcohol, individual talkers in all three cases could either increase or decrease  $F_0$ . In the present study, four talkers increased  $F_0$  and five decreased it; moreover, only three of the changes were significant: two of them decreased and one of them increased. Behne and Rivera (1990) reported general increases for four of six talkers, a decrease for one talker, and both an increase and a decrease (depending on the vowel) for a sixth talker. Künzel et al. (1992) reported that of 33 talkers,  $F_0$  increased for 25, decreased for 7, and remained unchanged for one. Whereas the results from these studies indicate a general trend toward increase in  $F_0$  under alcohol, Watanabe et al. (1994) reported decreases in  $F_0$  for both male and female talkers (decreases of means from 115 to 108 Hz for males, and 262 to 246 Hz for females). Finally, Johnson, Pisoni, and Bernacki (1990) reported that  $F_0$  was lower closer to the time

that their single subject (the captain of the U.S. Tankship *Exxon Valdez*) was alleged to have been intoxicated.

Although alcohol appears to exert no unique independent effect on mean  $F_0$ , results reported in the literature regarding pitch variability are more uniform. Pitch variability is measured in the literature on alcohol and speech in two ways: (1) as the standard deviation of  $F_0$  and (2) as jitter, that is, peak-to-peak variations in  $F_0$ . In the present study, the mean standard deviation of  $F_0$  across talkers increased significantly from the nonalcohol to the alcohol condition. Similar increases in standard deviation have been reported by Pisoni et al. (1985); Klingholz, Penning, and Liebhardt (1988); and Künzel et al. (1992). Similarly, increased jitter under alcohol was reported by Johnson et al. (1993), Künzel et al. (1992), Watanabe et al. (1994), and Cummings et al. (1996).

For the remaining acoustic parameters, alcohol appeared not to affect the probability of voicing for the keywords, indicating that words in sentential contexts were neither more nor less voiced under alcohol. Across talkers, AC peak was not affected by alcohol, but RMS amplitude was significantly higher in the alcohol condition. Increased RMS amplitude under alcohol was also reported by Johnson et al. (1993) for portions of sustained [a] and by Cummings et al. (1996) for the vowels in isolated words (using some of the same talkers as the present study).

The present study is the sixth from the General Motors/Indiana University database to appear in these progress reports (see Behne & Rivera, 1990; Behne et al. 1991; Cummings et al., 1995; Martin & Yuchtman, 1986; Pisoni et al., 1985). Results from these studies have shown that, for these nine talkers, the effects of alcohol (especially effects on duration) are consistent across various types of linguistic material, including isolated monosyllabic words, isolated spondaic words, sentences, and as demonstrated here, words produced in sentential contexts.

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