Journal of Speech and Hearing Research, Volume 39, 93–104, February 1996

Cognitive-Linguistic Demands and Speech Breathing

Heather L. Mitchell
Jeannette D. Hoit
Peter J. Watson
National Center for Neurogenic Communication Disorders
University of Arizona
Tucson

This investigation examined the influence of cognitive-linguistic processing demands on speech breathing. Twenty women were studied during performance of two speaking tasks that were designed to differ in cognitive-linguistic planning requirements. Speech breathing was monitored with respiratory magnetometers from which recordings were made of the antero-posterior diameter changes of the rib cage and abdomen. Results indicated that speech breathing was similar across speaking conditions with respect to nearly all measures of lung volume, rib cage volume, and abdomen volume. Task-related differences were found for certain fluency-related measures. Specifically, the number of syllables produced per breath group was smaller, average speaking rate was slower, and average lung volume expended per syllable was greater under a higher cognitive-linguistic demand condition than under a lower-demand condition. These differences were explained by the fact that silent pauses, particularly those associated with expiration, were more prevalent and longer in duration under the higher-demand condition. It appears that the mechanical behavior of the breathing apparatus during speaking generally is unaffected by variations in cognitive-linguistic demands of the type investigated; however, fluency-related breathing behavior appears to be highly sensitive to such demands.

KEY WORDS: speech breathing, cognitive-linguistic influence, extemporaneous speaking, pauses

The mechanical behavior of the normal breathing apparatus during connected speech production (e.g., reading and extemporaneous speaking) has been studied extensively (Hixon, Goldman, & Mead, 1973; Hixon, Mead, & Goldman, 1976; Hodge & Rochet, 1989; Hoit & Hixon, 1986, 1987; Hoit, Hixon, Altman, & Morgan, 1989; Hoit, Hixon, Watson, & Morgan, 1990; Hoit, Plassman, Lansing, & Hixon, 1988; Russell & Stathopoulos, 1988; Stathopoulos, Hoit, Hixon, Watson, & Solomon, 1991; Winkworth, Davis, Adams, & Ellis, 1995; Winkworth, Davis, Ellis, & Adams, 1994). In general, speech breathing has been found to be performed in the midrange of the vital capacity, involve larger rib cage volumes and smaller abdomen volumes than those associated with relaxation at prevailing lung volumes, and be associated with a predominantly rib cage contribution to lung volume change. Certain features of this general pattern have been shown to be influenced by physical and behavioral variables—for example, age (Hoit & Hixon, 1987; Hoit et al., 1988, 1989, 1990), body type (Hoit & Hixon, 1986), body position (Hixon et al., 1973, 1976; Hoit et al., 1988), speech loudness (Hixon et al., 1973, 1976; Russell & Stathopolous, 1988; Winkworth et al., 1994), and mood state (Winkworth et al., 1995).

Although many of the studies cited above (Hixon et al., 1973, 1976; Hoit et al., 1988, 1989, 1990; Hoit & Hixon, 1986, 1987; Winkworth et al., 1995) have included comparisons of linguistically constrained and unconstrained speaking tasks (reading and conversational speaking, respectively), relatively little is known about how cognitive-linguistic variables influence the mechanical behavior of the breathing apparatus. Most of the literature regarding the effect of cognitive-linguistic variables

  0022-4685/96/3901-0093

on speech breathing comes from research that has focused on the inspiratory phase of the speech breathing cycle and pauses within the expiratory phase. Such research has shown that subjects tend to place their inspirations at structural boundaries when reading aloud (Bless & Miller, 1972; Conrad, Thalacker, & Schönle, 1983; Grosjean & Collins, 1979; Henderson, Goldman-Eisler, & Skarbek, 1965; Hixon et al., 1973; Sugito, Ohyama, & Hirose, 1990) or speaking extemporaneously (Bless & Miller, 1972; Henderson et al., 1965; Hixon et al., 1973). Pauses within the expiratory phase of the speech breathing cycle associated with extemporaneous speaking appear to be related to cognitive activity associated with formulation of the spoken output (Goldman-Eisler, 1956; Henderson et al., 1965; Lay & Paivio, 1969; Reynolds & Paivio, 1968; Rochester, 1973; Taylor, 1969; Till & Goff, 1986). There is also some evidence to indicate that higher-cognitive demand activities are more likely to elicit breath holding than lower-demand activities (Webb, Williams, & Minifie, 1967). One recently published study (Winkworth et al., 1995) examined certain linguistic variables in relation to the full speech breathing cycle and showed that during spontaneous speaking inspirations usually preceded structural (clause) boundaries and that long breath groups were preceded by deeper inspirations more often than were short breath groups.

Thus, the existing literature indicates that certain features of the nonspeaking portion of the speech breathing cycle can be influenced by cognitive-linguistic variables. It seems reasonable, therefore, to predict that this influence might extend to the entire speech breathing cycle and that it might involve alterations in the general mechanical behavior of the breathing apparatus. The present investigation was designed to test this prediction.

Method

Subjects

Twenty healthy women served as subjects. Only women were included to control for sex-related differences in spoken-language characteristics and interactional styles within same-sex versus opposite-sex dyads (Shuy & Fasold, 1973; Tannen, 1990). Speech samples were elicited within a same-sex dyad (woman-woman), which included the first author. Subjects were 20 to 30 years of age, of average height and weight (Society of Actuaries and Association of Life Insurance Medical Directors of America, 1980), first-language General-American English speakers with normal speech and language, and enrolled as university students. Each passed a pure tone audiometric screening test for 0.5, 1.0, 2.0, 4.0, and 8.0 kHz presented at 25 dB SPL.

All subjects were in good respiratory health as determined by responses to a questionnaire and performances on selected respiratory function tests. Specifically, they were free of signs and symptoms suggestive of respiratory disease, without skeletal disease or abnormality affecting the chest wall, without history of surgery or injury involving the respiratory apparatus, without history of having smoked for at least 5 years (Tashkin et al., 1984), without history of prolonged exposure to high levels of dust or toxic agents, and free of allergies or respiratory infections on the day of testing. Respiratory function tests consisted of forced vital capacity maneuvers from which measures of forced vital capacity (FVC) and forced expiratory volume in 1 s (FEV_1) were obtained. Subjects were required to generate an FVC and FEV_1 that were at least 80% of the predicted value (Miller, 1986) for healthy women of corresponding age and height (Knudson, Lebowitz, Holberg, & Burrows, 1983).

All subjects were in good general health. They denied the presence of cardiac disease, neural disease, or any other serious medical condition, current use of medications with known stimulant or sedative effects, and the possibility of being pregnant. Data collection sessions were scheduled on days when subjects were free of menstrual discomfort.

Instrumentation

Speech breathing was studied by recording surface motions of the chest wall. In using this method, the chest wall is treated as a two-part system consisting of the rib cage and abdomen. Each part displaces volume as it moves and the sum of their displacements is equal to the volume displaced by the lungs. During breathing and speaking activities of the type performed by the present subjects, anteroposterior diameter changes of the rib cage and the abdomen are related linearly to their respective volume displacements. Therefore, diameter changes can be used to estimate directly the volume displaced by the individual parts (Hixon et al., 1973; Konno & Mead, 1967).

Anteroposterior diameter changes of the rib cage and abdomen were sensed with linearized magnetometers (GMG Scientific Inc., 1980) following the general procedure of Hoit and Hixon (1987). These magnetometers included two generator-sensor coils, one for the rib cage and one for the abdomen. The generator coil in each pair was attached to the front of the torso at the midline, one at sternal midlength and one just rostral to the umbilicus. The sensor coil in each pair was attached to the back of the torso at midline at the same axial level as its generator mate. Output signals from the two sensors were processed electronically and monitored on-line with a storage oscilloscope. The signals also were recorded on a videocassette data recorder for later analysis.

The speech audio signal was sensed by an air microphone and recorded on an audio channel of the data recorder. This signal provided a record of the subject's speech and allowed a means of synchronizing speech performance with breathing behavior. Video signals also were recorded synchronously with the kinematic data to allow for visual detection of movements or postural changes.

Performance Activities

The subject was seated upright in a chair especially constructed to accommodate the dorsal magnetometer coils. Each subject performed several chest wall maneuvers and speaking activities.

Chest wall maneuvers. Several chest wall maneuvers were included for the purpose of calibrating and normalizing the data (Hoit & Hixon, 1987). They included isovolume maneuvers, vital capacity maneuvers, abdomen capacity maneuvers, and relaxation maneuvers.

Isovolume maneuvers were performed to determine the functional relationship between the motions of the rib cage and abdomen from which volume-motion relationships were determined. Isovolume maneuvers were executed by having the subject close the larynx at the resting expiratory level and displace volume between the abdomen and rib cage by contracting and relaxing the abdominal muscles. Isovolume maneuvers were performed at the beginning and end of the recording session to ensure that no change in the volume-motion relationships had occurred.

Vital capacity maneuvers were performed to determine the subject's range of manipulable lung volumes and to normalize lung volumes across subjects. In addition, they were used to define the subject's rib cage capacity and to normalize rib cage volumes across subjects. To perform these maneuvers, the subject, wearing a noseclip and coupled to a respirometer, inspired fully from the resting expiratory level and then expired fully. The largest volume expired over three trials was taken as the subject's vital capacity. The minimum and maximum rib cage volumes produced during this maneuver were used to define the subject's rib cage capacity.

Abdomen capacity maneuvers were used to define the range of abdomen volumes for the subject and to normalize abdomen volumes across subjects. These maneuvers were performed by having the subject displace the abdomen inward maximally and outward maximally at the resting expiratory level while maintaining a closed larynx or upper airway.

Relaxation maneuvers were included so that inferences could be made regarding muscular pressures used during speech production. They were also included to help ensure that no postural changes had occurred. For these maneuvers, the subject was instructed to stop breathing at the resting expiratory level and to completely relax the breathing muscles. Successful relaxation maneuvers were characterized by assumption of a repeatable chest wall configuration and involved no change in lung volume. Relaxation maneuvers were performed several times throughout the recording session.

Speaking activities. The speaking activities included two tasks, designed to differ in cognitive-linguistic demands, and two topics, matched on difficulty and emotionality. The first task, the higher-demand task (hereinafter referred to as the No-Outline Task), involved having the subject speak extemporaneously on a designated topic. More specifically, following performance of the chest wall maneuvers, the subject was told that she would be asked to speak on a specific topic for about 3 min and that she would be told when to stop. She was then given the topic. Once a stable baseline of resting tidal breathing was established and a relaxation maneuver had been performed (usually a time lapse of less than 1 min), she was asked to begin speaking on that topic. If the subject experienced difficulty before the 3 min had elapsed, as evidenced by verbal or nonverbal indicators (e.g., "I don't know what else to say," head shaking), she was cued with the statement, "You may discuss the topic any way you'd like." If, after 15 s, she failed to respond to cuing and did not continue speaking, the activity was terminated. The duration of this first speaking sample was used as the cut-off time for the subsequent speaking activities for that subject.

Immediately thereafter, the subject was asked to prepare a written outline on the same topic that she could use while speaking. She was told that she would be asked to speak on the topic once again for the same amount of time and that she could repeat anything that she had said before. A table (with paper and pen) was rolled up to the subject so that her general body position remained constant. When the subject indicated that she had finished constructing her outline, the table was removed and the subject was asked to sit quietly. When resting tidal breathing was determined to be stable and the subject had performed another relaxation maneuver (usually within 1 min), the subject spoke once again on the same topic, but this time using her written outline as a guide. The subject was signaled to stop speaking at approximately the same time she had stopped during her first discussion of the topic. This speaking task (hereinafter referred to as the Outline Task) was assumed to be lower in cognitive-linguistic demands than the first task because the content of the discourse was preplanned and available to the subject in the form of visual cues.

The No-Outline and Outline Tasks were repeated with discussion of a second topic, using the same instructions and speaking cut-off time. The two topics were "Quality of education in the United States" (hereinafter referred to as Education Topic) and "The effect of television violence on children" (hereinafter referred to as Television-Violence Topic). These topics were judged to be moderate in difficulty and emotionality.[1] (See footnote next page.) They were selected with the intention of (a) providing an adequate conceptual challenge for the subjects without being so difficult as to inhibit verbal output, and (b) avoiding the influence of high emotional arousal on speech breathing behavior (Goldman-Eisler, 1955; Reynolds & Paivio, 1968). The order of topic presentation was counterbalanced across subjects.

Post-Investigation Subject Report

Immediately following collection of speech breathing data, the subject was given a rating form to ascertain her perception of the difficulty and emotionality of each topic/task combination. The primary purpose of obtaining difficulty ratings was to determine if the No-Outline Task was perceived by subjects as being more difficult than the Outline Task, as intended in the design of the two tasks. The primary purpose of including emotionality ratings was to determine if the perceived emotionality of the subject's experience differed under the two task conditions. Were this the case, it would aid in the interpretation of possible performance differences. Also, ratings of difficulty and emotionality might have helped explain topic-related performance differences had they been found. These ratings were obtained by having the subject mark a visual-analog scale. Perceived difficulty and emotionality were rated separately. Definitions of difficulty and emotionality were not provided.

In addition, the subject was asked to write a brief description of her familiarity with each topic. This was included to help explain topic-related performance differences had they been found.

Data Analysis

Data recorded during each subject's "speaking time" were analyzed. Speaking time was defined as the duration of the first speaking activity performed and was used as the cut-off for subsequent speaking activities. A variety of descriptive and inferential statistical tests were applied to the data. For inferential testing, an alpha level of .01 was used.

Linguistic data. The linguistic data were analyzed to obtain a measure of the complexity and organization of concepts presented in the subjects' spoken output as well as to indicate whether or not the No-Outline and Outline Tasks involved different cognitive-linguistic activities. The measure was based on transcriptions of the four speech samples generated by each subject (Education Topic/No-Outline Task, Education Topic/Outline Task, Television-Violence Topic/No-Outline Task, Television-Violence Topic/Outline Task). These transcripts contained all fillers and revisions, but no punctuation.

Each transcript was analyzed using a procedure adapted from an analysis for written language described by Flower (1989). Formally referred to as "issue tree analysis," this procedure involved the construction of a hierarchical structure that depicted the relationship among the ideas presented within the discourse while preserving their sequence. Ideas were categorized either as Subtopics, which were ideas related directly to the main topic, or as Subordinates, which were ideas that elaborated on a Subtopic. For each of the 80 issue trees constructed (20 subjects × 4 speech samples), the number of Subtopics was counted and a rating reflecting the number of Subordinates per Subtopic was assigned. A rating of "0" indicated that the Subtopic contained no Subordinates, a rating of "1" indicated that the Subtopic contained one Subordinate, and a rating of "2" indicated that a Subtopic contained two or more Subordinates.

For each transcript, the number of Subtopics was divided into the sum of the Subordinate ratings. The resultant quotient reflected the average "amount of detail" devoted to Subtopics. Thus, the higher the quotient, the more "in depth" the content of the response.

Respiratory kinematic data. Consecutive speech breathing cycles produced within each subject's designated speaking time were analyzed. Only those cycles containing swallows, laughs, or extraneous sounds (e.g., lip smacks) were excluded from the analysis. Volume, temporal, and syllable-related measures were obtained.

Volume measures were made from expiratory phases of speech breathing cycles as follows. To begin, a data chart, such as that described by Hoit and Hixon (1987), was created for each subject with the aid of customized software from recordings of the chest wall maneuvers. In the chart, percent rib cage capacity (%RCC) was shown on the vertical axis, increasing upward, with 0 and 100% representing the smallest and largest rib cage volumes, respectively. Percent abdomen capacity (%ABC) was shown on the horizontal axis, increasing rightward, with 0 and 100% representing the smallest and largest abdomen volumes, respectively. Percent vital capacity (%VC) was indicated on a diagonal axis, increasing upward and rightward, with 0 and 100% representing the smallest and largest lung volumes, respectively. Following the construction of the chart, the data were displayed on the computer and the following measurements were made from each expiratory limb: (a) lung volume initiation, termination, and excursion (LVI, LVT, and LVE, in %VC); (b) rib cage volume initiation, termination, and excursion (RCVI, RCVT, and RCVE, in %RCC); (c) abdomen volume initiation, termination, and excursion (ABVI, ABVT, and ABVE, in %ABC); and (d) relative volume contribution of the rib cage (in percentage rib cage, %RC).

Temporal measures were obtained from time-motion plots of the summed rib cage and abdomen signals (i.e., lung volume) displayed along with the audio signal. Durations (in s) of inspiratory and expiratory phases were determined for each speech breathing cycle.

Three measures related to syllable production were obtained for each breath group: number of syllables per breath group, average speech rate (in syllables/s), and average lung volume expended per syllable (in cc/syllable). The number of

[1]Topic selection was accomplished, in part, by conducting a survey of 20 female university students, age 20 to 30 years, who were not subjects in the investigation proper. These students were presented with a list of 20 topics and were instructed to imagine that they would be asked to discuss these topics for 2 to 3 min. They were then instructed to rate each topic on a 5-point scale with respect to both "difficulty" and "emotionality," with 1 representing the *lowest* difficulty/emotionality and 5 representing the *highest* difficulty/emotionality. The mean ratings obtained for each topic included in the survey are given below.

	Topic	Difficulty Rating	Emotionality Rating
1.	Quality of education in the United States	2.9	3.0
2.	Your favorite vacation	1.2	3.4
3.	The effect of television violence on children	3.1	3.2
4.	Describe your hometown	1.3	3.1
5.	Describe your favorite hobbies	1.8	2.8
6.	Your future goals and aspirations	2.3	3.7
7.	The importance or unimportance of environmentalism	2 7	3.7
8.	Your definition of peace	3.4	3.6
9.	Career opportunities within your major	2.1	2.9
10.	The benefits of exercise	1.6	2.6
11.	The issue of rising medical costs	3.4	3.2
12.	Your views on the death penalty	3.5	3.5
13.	Your current courseload, including your likes and dislikes	1.4	3.4
14.	The problems you will face as you get older	3.2	3.0
15.	The plight of the homeless	3.0	3.9
16.	Describe your favorite movie	1.5	2.8
17.	Discuss your religious beliefs	2.8	3.8
18.	Discuss your typical weekend activities	1.2	1.9
19.	Describe your best or closest friend	1.7	3.5
20.	Describe your favorite kind of music	2.1	2.9

Topics with mean difficulty ratings of approximately 3 (considered "moderate") and mean emotionality ratings of 3 or lower were judged to be appropriate for use in the investigation proper. The two topics selected for the investigation proper were: "Quality of education in the United States" and "The effect of television violence on children," with mean difficulty ratings of 2.9 and 3.1, respectively, and mean emotionality ratings of 3.0 and 3.2, respectively.

syllables per breath was tabulated from transcripts that had been marked for inspiratory/expiratory boundaries. Speech rate was determined by dividing the number of syllables by the expiratory duration. Lung volume expended per syllable was calculated by dividing the lung volume excursion by the number of syllables spoken.

Post-investigation subject report data. Ratings of difficulty and emotionality were analyzed by converting each subject's marks on the visual-analog scale to rankings for the two topics (Education Topic vs. Television-Violence Topic) and the two tasks (No-Outline Task vs. Outline Task). Subjects' written descriptions of topic familiarity were analyzed by reading them and assigning each a rating of Low, Medium, or High familiarity.

Results

Speaking times (i.e., durations of the initial speech sample for each subject) ranged from 1:30 (min:s) to 2:50 and averaged 2:26. All but one subject had speaking times that exceeded 2 min. Results obtained from linguistic and respiratory kinematic data generated within those time periods are reported below.

Linguistic Data

Analysis of the linguistic data indicated that the No-Outline Task had a smaller quotient (i.e., sum of Subordinate ratings divided by number of Subtopics) than the Outline Task in 35/40 (88%) of the cases. A 2 (topic) × 2 (task) analysis of variance (ANOVA) with repeated measures on both factors revealed a significant main effect for task [$F(1,19) = 78.24$, $p < .001$]. There was no main effect for topic [$F(1,19) = 4.04$, $p = .059$] and no significant interaction [$F(1,19) = 0.26$, $p = .615$]. This indicates that subjects discussed topics in greater depth during the Outline Task than during the No-Outline Task.

Respiratory Kinematic Data

Table 1 contains group means and standard deviations for all measures obtained for the Education Topic and the Television-Violence Topic for the No-Outline Task and the Outline Task. Largest mean differences across topic/task conditions were 0.96 %VC for LVI, 2.07 %VC for LVT, 1.11 %VC for LVE, 0.47 %RCC for RCVI, 2.17 %RCC for RCVT, 1.83 %RCC for RCVE, 3.80 %ABC for ABVI, 5.15 %ABC for ABVT, 1.39 %ABC for ABVE, 2.99 %RC for relative volume contribution, 0.07 s for inspiratory duration, 0.25 s for expiratory duration, 2.45 for syllables/breath, 0.43 for syllables/s, and 13.05 for cc/syllable. Results of 2 (topic) by 2 (task) ANOVAs with repeated measures on both factors are shown in Table 2. These analyses revealed a significant ($p < .01$) main effect for Task on ABVT, syllables/breath, syllables/s, and cc/syllable.

Because the order of topic presentation had been counterbalanced, additional analyses were carried out to determine if there were order effects on subject performance. Table 3 contains group means and standard deviations for all measures obtained for First and Second Topics for the No-Outline and Outline Tasks. Largest mean differences across topic order/task conditions were 1.48 %VC for LVI, 1.42 %VC for LVT, 0.57 %VC for LVE, 1.07 %RCC for RCVI, 2.27 %RCC for RCVT, 1.39 %RCC for RCVE, 3.67 %ABC for ABVI, 4.44 %ABC for ABVT, 1.38 %ABC for ABVE, 3.19

TABLE 1. Group means and standard deviations of measures for the Education and Television-Violence Topics for the No-Outline and Outline Tasks.

	Education				Television Violence			
	No-Outline		Outline		No-Outline		Outline	
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
LVI	46.35	7.94	47.17	6.39	47.31	8.52	47.01	7.67
LVT	32.75	8.08	33.62	6.05	34.82	8.26	34.24	7.06
LVE	13.60	3.13	13.55	2.40	12.49	2.34	12.77	2.12
RCVI	46.18	12.25	46.31	11.45	46.65	12.93	46.22	12.45
RCVT	29.20	10.51	28.90	9.97	31.07	11.70	29.45	11.60
RCVE	16.98	4.47	17.41	3.71	15.58	3.42	16.77	3.62
ABVI	73.04	14.63	76.41	13.16	76.84	15.50	76.81	13.04
ABVT	65.30	14.74	69.89	12.58	69.61	14.76	70.45	11.77
ABVE	7.74	4.90	6.52	3.72	7.22	5.19	6.35	4.41
RVC	84.23	12.69	86.31	11.48	85.38	12.97	87.22	12.29
Insp Dur	0.72	0.18	0.68	0.15	0.75	0.15	0.69	0.13
Exp Dur	4.15	1.07	4.25	1.01	4.00	0.90	4.15	0.83
Syll/br	17.19	4.55	18.45	4.62	16.00	4.19	17.28	3.66
Syll/s	4.09	0.53	4.34	0.48	3.91	0.40	4.20	0.30
cc/syll	43.31	18.08	30.26	8.18	41.81	15.88	31.15	6.25

Note: LVI = lung volume initiation (in percent vital capacity, %VC). LVT = lung volume termination (in %VC). LVE = lung volume excursion (in %VC). RCVI = rib cage volume initiation (in percent rib cage capacity, %RCC). RCVT = rib cage volume termination (in %RCC). RCVE = rib cage volume excursion (in %RCC). ABVI = abdomen volume initiation (in percent abdomen capacity, %ABC). ABVT = abdomen volume termination (in %ABC). ABVE = abdomen volume excursion (in %ABC). RVC = relative volume contribution (in %RC). Insp Dur = inspiratory duration (in s). Exp Dur = expiratory duration (in s). Syll/br = syllables/breath group. Syll/s = syllables/s. cc/syll = cc/syllable.

TABLE 2. Results of 2 (topic) × 2 (task) analysis of variance with repeated measures on both factors (*df* = 1,19).

	Topic		Task		Interaction	
Measure	*F*	*p*	*F*	*p*	*F*	*p*
LVI	0.30	.591	0.13	.718	0.64	.435
LVT	2.63	.121	0.03	.865	1.38	.255
LVE	7.07	.016	0.20	.657	0.51	.484
RCVI	0.05	.834	0.03	.872	0.13	.722
RCVT	2.03	.170	0.93	.347	0.83	.373
RCVE	5.69	.028	5.57	.029	1.80	.196
ABVI	2.03	.171	4.83	.041	2.25	.150
ABVT	3.09	.095	9.04	.007*	2.45	.134
ABVE	0.40	.536	5.94	.025	0.27	.607
RVC	1.18	.291	5.48	.030	0.02	.891
Insp Dur	1.20	.288	6.97	.016	0.32	.579
Exp Dur	1.49	.237	2.74	.115	0.14	.709
Syll/br	6.77	.018	21.00	.001*	0.00	.976
Syll/s	3.80	.066	14.11	.001*	0.12	.730
cc/syll	0.01	.910	22.75	.001*	0.24	.633

Note. See note to Table 1 for explanation of Measures.
$^{*}p < .01$

%RC for relative volume contribution, 0.08 s for inspiratory duration, 0.29 s for expiratory duration, 2.19 for syllables/breath, 0.35 for syllables/s, and 17.91 for cc/syllable. Results of 2 (topic order) by 2 (task) ANOVAs with repeated measures on both factors, shown in Table 4, revealed a significant main effect for task on ABVT, syllables/s, and cc/syllable and a significant interaction on syllables/breath. Tukey's Honestly Significant Difference (HSD) post hoc contrasts of all order/task combinations revealed significant differences between First Topic/No-Outline Task and First Topic/Outline Task and First Topic/No-Outline Task and Second Topic/Outline Task.

Post-Investigation Subject Report Data

Difficulty. Difficulty ratings obtained from the Post-Investigation Subject Reports were converted to rankings. The mean rankings, with 1 representing *lowest* difficulty and 4 representing *highest* difficulty, were as follows: Education Topic/No-Outline Task = 3.00, Education Topic/Outline Task = 1.38, Television-Violence Topic/No-Outline Task = 3.70, Television-Violence Topic/Outline Task = 1.93. A Friedman's 2 (topic) × 2 (task) ANOVA revealed a significant difference [$\chi^2(3) = 39.44$, $p < .01$]. Nemenyi's post hoc contrasts revealed significant differences ($p < .01$) between Education Topic/No-Outline Task and Education Topic/Outline Task, Television-Violence Topic/No-Outline Task and Television-Violence Topic/Outline Task, and Television-Violence Topic/No-Outline Task and Education Topic/Outline Task.

A similar analysis was completed for the First and Second Topics presented. The mean rankings were First Topic/No-

TABLE 4. Results of 2 (topic order) × 2 (task) analysis of variance with repeated measures on both factors (df = 1,19).

	Order		Task		Interaction	
Measure	*F*	*p*	*F*	*p*	*F*	*p*
LVI	0.33	.574	0.13	.718	2.50	.130
LVT	0.01	.941	0.03	.865	5.07	.036
LVE	0.78	.390	0.20	.657	0.91	.351
RCVI	0.07	.794	0.03	.872	1.21	.284
RCVT	0.15	.704	0.93	.347	3.73	.069
RCVE	1.56	.227	5.57	.029	2.95	.102
ABVI	0.14	.710	4.83	.041	3.30	.085
ABVT	0.39	.540	9.04	.007*	2.02	.171
ABVE	0.39	.538	5.94	.025	0.76	.396
RVC	1.70	.208	5.48	.030	0.84	.370
Insp Dur	3.38	.082	6.97	.016	1.26	.276
Exp Dur	1.25	.277	2.74	.115	7.49	.013
Syll/br	0.82	.375	21.00	.001*	11.16	.003*
Syll/s	0.37	.550	14.11	.001*	4.12	.057
cc/syll	7.48	.013	22.75	.001*	5.17	.035

Note: See note to Table 1 for explanation of Measures. Follow-up testing indicated significant ($p < .01$) differences between the First Topic/No-Outline Task and First Topic/Outline Task, and First Topic/No-Outline Task and Second Topic/Outline Task for Syll/br.
$^{*}p < .01$

TABLE 3. Group means and standard deviations of measures for the First and Second Topics for the No-Outline and Outline Tasks.

	First Topic				Second Topic			
	No-Outline		Outline		No-Outline		Outline	
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
LVI	47.15	8.86	46.35	7.38	46.41	7.59	47.83	6.63
LVT	34.39	8.67	33.25	6.96	33.18	7.74	34.60	6.10
LVE	12.76	2.60	13.09	2.10	13.33	2.99	13.23	2.48
RCVI	46.71	13.96	45.73	12.07	46.12	11.06	46.80	11.82
RCVT	30.96	12.02	28.69	10.91	29.31	10.16	29.66	10.71
RCVE	15.75	3.86	17.04	3.23	16.81	4.15	17.14	4.08
ABVI	75.65	14.68	75.31	13.34	74.23	15.66	77.90	12.72
ABVT	67.86	14.69	68.85	12.36	67.06	15.12	71.50	11.86
ABVE	7.79	5.00	6.46	3.46	7.17	5.09	6.41	4.61
RVC	83.80	12.68	86.55	11.19	85.81	12.93	86.99	12.58
Insp Dur	0.76	0.16	0.69	0.14	0.72	0.17	0.68	0.14
Exp Dur	3.93	0.93	4.22	0.85	4.22	1.03	4.17	1.00
Syll/br	15.90	4.29	18.09	4.01	17.29	4.43	17.63	4.39
Syll/s	3.93	0.59	4.28	0.45	4.07	0.33	4.26	0.35
cc/syll	48.09	19.82	31.23	7.33	37.03	11.10	30.18	7.23

Note. See note to Table 1 for explanation of Measures.

Outline Task = 3.53, First Topic/Outline Task = 1.85, Second Topic/No-Outline Task = 3.28, and Second Topic/Outline Task = 1.50. A Friedman's 2 (topic order) × 2 (task) ANOVA revealed a significant difference [$\chi^2(3) = 34.37$, $p < .01$]. Nemenyi's post hoc contrasts revealed significant differences ($p < .01$) between First Topic/No-Outline Task and First Topic/Outline Task, First Topic/No-Outline Task and Second Topic/Outline Task, First Topic/Outline Task and Second Topic/No-Outline Task, and Second Topic/No-Outline Task and Second Topic/Outline Task.

Emotionality. Emotionality ratings also were converted to rankings, with 1 representing the *lowest* emotionality and 4 representing the *highest* emotionality. The mean rankings were Education Topic/No-Outline Task = 2.83, Education Topic/Outline Task = 1.75, Television-Violence Topic/Outline Task = 3.05, and Television-Violence Topic/Outline Task = 2.38. A Friedman's 2 (topic) × 2 (task) ANOVA showed no significant difference [$\chi^2(3) = 11.84$, $p = .01$].

For the First and Second Topics presented, mean rankings were First Topic/No-Outline Task = 3.20, First Topic/Outline Task = 2.25, Second Topic/No-Outline Task = 2.60, and Second Topic/Outline Task = 1.95. A Friedman's 2 (topic order) × 2 (task) ANOVA was not significant [$\chi^2(3) = 10.38$, $p = .02$].

Familiarity. For the Education Topic, familiarity was judged to be Low for 5 subjects (25%), Medium for 12 subjects (60%), and High for 3 subjects (15%). For the Television-Violence Topic, familiarity was judged to be Low for 14 subjects (70%) and Medium for 6 subjects (30%).

Summary

Analysis of the linguistic data indicated that the no-outline condition was associated with fewer Subordinates per Subtopic when compared to the outline condition, suggesting that discussion of the topics was less "in depth" (more superficial) without the outline. Examination of speech breathing data indicated that subjects performed similarly across topic/task conditions on most measures. Exceptions were abdomen volume termination (which was smaller for the no-outline condition), syllables/breath group (which was smaller for the first topic presented under the no-outline condition as compared to both topics under the outline condition), syllables/s (which was smaller for the no-outline condition), and cc/syllable (which was larger for the no-outline condition). Post-investigation report data showed that subjects generally rated the no-outline condition as more difficult than the outline condition. There were no differences in their ratings of emotionality across conditions. Regarding ratings of familiarity, subjects reported being somewhat more familiar with the Education Topic than Television-Violence Topic; however, this did not turn out to be important because no topic-related differences were found.

Table 5 provides a summary of the task-related differences. In it are listed the significant differences (and the direction of differences) between the No-Outline and Outline Tasks for the linguistic measure, speech breathing measures, and perceptual rating measures.

TABLE 5. Summary of the significant differences in the linguistic measure, speech breathing measures, and perceptual ratings for the No-Outline and Outline Tasks.

Measure	No-Outline:Outline
Linguistic	
Subordinates/Subtopic	$<$
Speech breathing	
Abdomen volume termination	$<$
Syllables/breath group	$<$*
Syllables/s	$<$
cc/syllable	$>$
Perceptual rating	
Difficulty	$>$

*Significant differences were between the First Topic for the No-Outline Task and the First and Second Topics for the Outline Task.

Post Hoc Analyses

The results summarized above indicated that, although there was a paucity of differences observed in the mechanical aspects of speech breathing, there were substantial differences in measures related to speech fluency (i.e., syllables/breath group, syllables/s, and cc/syllable). Specifically, subjects were found to produce fewer syllables per breath group, speak at slower overall rates, and expend greater volumes of air per syllable on average for the No-Outline Task than for the Outline Task. Further, these patterns were most apparent on the First Topic discussed, reaching statistical significance for one of the three measures (syllable/breath group).

Several potential explanations for these differences were considered, including the possibility that subjects spoke at slower syllable-by-syllable rates and that they spoke using continually higher air flows for the No-Outline Task, particularly during its first performance, than for the Outline Task. However, review of the audio recordings revealed nothing to suggest that these were reasonable avenues to pursue. Rather, the most potentially powerful explanation for the observed differences appeared to involve pause-related phenomena.

Thus, additional analyses were performed that involved measurement of both silent pauses and filled pauses. Beginning with the former, a silent pause was defined as a silent period of at least 250 ms (Butterworth, 1980; Greene, 1984) produced during the expiratory phase of speech breathing cycles. Inspiratory pauses were not analyzed. Silent pauses were identified by viewing the audio signal along with the lung volume signal (i.e., the summed rib cage and abdomen signals) using time-motion displays. Each pause was measured for duration using cursors and was categorized according to pause type. For analysis purposes, each silent pause was categorized as either a breath-hold pause (i.e., one associated with no change in lung volume) or an expiratory pause (i.e., one associated with expiration). An expiratory pause could be associated with expiration only or with a combination of expiration and periods of no lung volume change.

Table 6 contains group means and standard deviations of the number and duration (in s) of breath-hold pauses and expiratory pauses for each task/topic combination. As can

TABLE 6. Group means (and standard deviations) of the number of silent pauses and their durations (in s), tabulated by pause type, for the First and Second Topics during performance of the No-Outline and Outline Tasks.

	Breath-Hold Pause		Expiratory Pause	
Task	Number	Duration	Number	Duration
No-Outline				
First Topic	10.25 (7.33)	0.57 (0.24)	25.75 (10.01)	0.58 (0.13)
Second Topic	11.00 (9.26)	0.60 (0.14)	22.45 (10.12)	0.55 (0.11)
Outline				
First Topic	12.11 (8.11)	0.59 (0.18)	24.05 (10.08)	0.51 (0.08)
Second Topic	12.30 (9.33)	0.57 (0.16)	21.65 (9.26)	0.49 (0.10)

be seen in the table, the average number of silent pauses per speaking activity ranged from 10.25 to 25.75, and the average duration ranged from 0.49 to 0.60 s. Because speaking time differed from subject to subject (ranging from 1 min, 30 s to 2 min, 50 s), silent pauses were normalized for the purpose of performing inferential analyses. This was done by summing each subject's silent pause durations (by pause type) for a given speaking activity and dividing that sum by the total expiratory duration for that speaking activity. Table 7 provides the means and standard deviations of the total pause duration, expressed as a percentage of expiratory duration, for the No-Outline and Outline Tasks for the First and Second Topics. Average durations ranged from 5.29% to 14.45%. As shown in Table 8, a 2 (topic order) by 2 (task) by 2 (pause type) ANOVA with repeated measures on all three factors revealed a significant ($p < .01$) main effect for order and pause type and a significant interaction for order by pause type. Tukey's HSD post hoc contrasts of all order-pause type combinations revealed significant differences between the breath-hold and expiratory pauses for both the First and Second Topics, and between expiratory pauses for the First and Second Topics. These results indicate that a greater percentage of expiratory time was spent producing expiratory pauses compared to breath-hold pauses, and that a greater percentage of time was spent producing expiratory pauses during discussion of the First Topic compared to the Second Topic.

TABLE 7. Group means (and standard deviations) of silent pause duration (expressed as a percentage of expiratory duration), tabulated by type, for the First and Second Topics during performance of the No-Outline and Outline Tasks.

Task	Breath-Hold Pause	Expiratory Pause
No-Outline		
First Topic	5.99 (5.74)	14.45 (8.84)
Second Topic	5.29 (4.65)	10.04 (5.69)
Outline		
First Topic	5.78 (3.49)	10.90 (5.66)
Second Topic	5.92 (5.42)	8.85 (4.78)

In addition to examining silent pauses, consideration also was given to the prevalence of filled pauses. These were counted from the subjects' transcripts. Filled pauses that were most likely to represent "prolonged" syllables were included in the count. For the present subjects, these filled pauses consisted of single-syllable nonlinguistic utterances (*uh*, *ah*, *mm*, *um*, *hum*, and *er*). Utterances such as *you know* were not included because it seemed less likely that these were associated with prolonged syllable production. Filled pause counts were expressed in normalized form by dividing the number of filled pauses by the number of total syllables produced by each subject for each speaking activity. The prevalence of filled pauses within a given speech sample ranged from 0.0% to 7.3% of the total number of syllables; however, the vast majority of speech samples contained less than 3.0%. A 2 (topic order) by 2 (task) ANOVA with repeated measures on both factors indicated that there were no significant main effects for order [$F\,(1,58) = 0.11$, $p = .736$] or task [$F\,(1,58) = 0.69$, $p = .409$] and no significant interaction [$F\,(1,58) = 0.66$, $p = .421$].

Discussion

This investigation was conducted to examine the influence of cognitive-linguistic demands on speech breathing. Its design took into account the importance of studying a relatively homogenous group of subjects, using noninvasive and relatively unencumbering observational procedures, including speaking tasks that varied primarily with respect to the degree of formulation required, and accounting for the perceived difficulty and emotionality associated with performance of these tasks. The results of this investigation revealed that the mechanical behavior of the breathing apparatus during speech production was essentially unaffected by changes in cognitive-linguistic demands, but that variables related to speech fluency were highly sensitive to these demands. The following discussion covers issues related to speech breathing mechanics and cognitive-linguistic demands, speech fluency and cognitive-linguistic demands, and offers conclusions drawn from this research.

Speech Breathing Mechanics and Cognitive-Linguistic Demands

Speech breathing in these 20 young women resembled that of previously studied adults (Hixon et al., 1973, 1976; Hodge & Rochet, 1989; Hoit & Hixon, 1986, 1987; Hoit et al., 1988, 1989; Russell & Stathopoulos, 1988; Stathopoulos et al., 1991; Winkworth et al., 1994, 1995). Briefly, speech was produced in the midrange of the vital capacity, near the resting expiratory level, and encompassed between 10% and 15% of the vital capacity. Change in lung volume was accomplished using predominantly rib cage contribution. Inspiratory phases of speech breathing cycles were substantially shorter than expiratory phases. Speech breathing involved abdomen volumes that were smaller and rib cage volumes that were larger than those associated with relax-

TABLE 8. Results of a 2 (topic order) × 2 (task) × 2 (pause type) ANOVA with repeated measures on all factors for measures of pause duration (in percentage expiratory duration).

	F	*df*	*p*
Task	4.53	1,18	.048
Order	13.05	1,18	.002*
Pause Type	11.48	1,18	.003*
Task × Order	5.80	1,18	.027
Task × Pause Type	3.57	1,18	.075
Order × Pause Type	11.34	1,18	.003*

Contrasts

	First Topic/ Breath-Hold	Second Topic/ Breath-Hold	First Topic/ Expiratory	Second Topic/ Expiratory
First Topic/ Breath-Hold			*	*
Second Topic/ Breath-Hold			*	*
First Topic/ Expiratory				*
Second Topic/ Expiratory				

*Significant at the .01 level

ation at the prevailing lung volumes. These kinematic patterns have been shown to be produced by a combination of expiratory rib cage and abdomen muscular pressures, with the latter predominating, and efforts of the diaphragm during inspiration (Hixon et al., 1976).

When speech breathing performance elicited under the two speaking conditions was contrasted, the mechanical behavior of the breathing apparatus was found to differ in only one feature. Specifically, the volume of the abdomen at breath group termination was smaller on average under the higher cognitive-linguistic demand condition (No-Outline Task) than the lower-demand condition (Outline Task). The difference was slight, less than 5 %ABC on average. It is possible that a smaller abdomen termination volume was associated with greater abdominal muscle activity, but there is no evidence available to support this. Without additional information to aid in the interpretation of this finding, the functional significance of this statistical difference is unknown.

More interesting perhaps than this single difference was the fact that all other measures related to the mechanical behavior of the breathing apparatus were not different between the two speaking conditions. That is, lung volume events, rib cage volume events, most abdomen volume events, relative volume contribution of the rib cage and abdomen, and inspiratory and expiratory durations did not differ when the cognitive-linguistic demands of the speaking task were altered. This indicates that the mechanical behavior of the breathing apparatus during speech production is essentially unaffected by cognitive-linguistic "load," at least under the types of speaking conditions included in this investigation.

It is relevant to consider the question of whether or not the two speaking tasks employed in this investigation actually represented two different levels of cognitive-linguistic demand. If not, this could explain the lack of differences observed in speech breathing behavior. Results of the post-investigation reports suggested, however, that they did, in fact, differ. Specifically, subjects' ratings of the "difficulty" they experienced during performance of the various topic/task combinations indicated that they perceived speaking extemporaneously (No-Outline Task) as more difficult than speaking with the aid of an outline (Outline Task). It is also of interest to note that linguistic analyses indicated that subjects organized their linguistic output differently, depending on whether or not a self-generated outline was available. Despite the fact that cognitive-linguistic demands imposed by these two speaking tasks appeared to differ in nature and magnitude, it could be argued that the contrast between them was not sufficient to influence the mechanical behavior of the breathing apparatus. The possibility remains that pairing an extremely simple task, such as recitation of a memorized passage, with an extremely difficult task, such as extemporaneous discussion of highly complex topics, could elicit divergent mechanical behavior.

Speech Fluency and Cognitive-Linguistic Demands

A subset of the variables examined in this investigation were related to speech fluency, and included the number of syllables produced per breath group, speaking rate, and average volume of air expended per syllable. The values obtained in this investigation were similar to those reported by others for syllables/breath group (Hoit & Hixon, 1987; Hoit et al., 1989; Hodge & Rochet, 1989; Solomon & Hixon, 1993; Till & Goff, 1986), syllables/s (Hodge & Rochet, 1989; Lass & Clegg, 1973; Solomon & Hixon, 1993; Till & Goff, 1986), and cc/syllable (Hoit et al., 1989).

Although the values obtained were in the expected range for normal subjects, the present results indicated that their magnitudes were influenced by the nature of the speaking activity and the order in which it was performed. In brief, the number of syllables produced per breath group was smaller, speaking rate was slower, and the average volume of air expended per syllable was greater during performance of the extemporaneous speaking task (No-Outline Task) compared to the task involving the use of an outline (Outline Task). These patterns were particularly apparent during the initial performance of the extemporaneous speaking task.

Of the factors considered, pause-related behavior appeared to have the greatest potential for explaining these findings. Post hoc analyses indicated that, although all subjects produced both silent pauses and filled pauses, only silent pauses were candidates for helping to explain differences in the fluency-related measures of interest. Specifically, these analyses indicated that the amount of time spent pausing silently (expressed in normalized form relative to the total expiratory duration) was greatest during performance of the initial speaking activity, that is, speaking without an outline about the first topic presented. The fact that subjects spent relatively more time pausing meant that they spent relatively less time speaking. Thus, they produced fewer syllables per breath group and spoke at a slower overall speaking rate when rate was determined with pause time included in the calculation. This relation of increased pause time to slower overall speaking rate has been pointed out previously (Goldman-Eisler, 1956).

To gain insight into why the average cc/syllable differed with speaking activity, each silent pause was categorized according to whether or not it was accompanied by expiration. Examination of silent pause by type revealed that relatively more time was spent producing expiratory pauses (i.e., pauses accompanied by expiration) during performance of the initial speaking activity when compared to the subsequent activities. Thus, subjects tended to pause and "waste" air when speaking extemporaneously on a topic, particularly when the task was attempted for the first time. This accounts, at least in part, for why cc/syllable values, when averaged across the breath group, were larger (by 11 to 18 cc/syllable) for the first speaking activity (First Topic/No Outline Task) compared to the other speaking activities.

The question arises as to why subjects paused more during the initial speaking activity. Although there are probably several contributing factors, one major factor appears to be related to task difficulty. The initial speaking activity involved speaking extemporaneously about a topic without benefit of preparation. When asked to provide ratings of "difficulty" in the post-investigation report, subjects generally rated the extemporaneous speaking task as more difficult than the outline-guided task. This finding agrees with previous work, which has shown that silent pauses tend to be more numerous and longer in duration during performance of difficult speaking tasks compared to easier speaking tasks (Green, 1984; Green & Cappella, 1986; Lay & Paivio, 1969; Reynolds & Paivio, 1968; Taylor, 1969). Silent pauses (also sometimes referred to as halts or hesitations) have been hypothesized to represent behavioral evidence that subjects are formulating the ensuing verbal output (Goldman-Eisler, 1956; Greene, 1984; Green & Cappella, 1986; Lay & Paivio, 1969; Reynolds & Paivio, 1968; Rochester, 1973; Taylor, 1969).

Emotion-related variables also may have contributed to pausing behavior in these subjects. To some extent, the design of this investigation took into account the issue of emotionality. To begin, the topics selected for discussion were ones that had been rated as no greater than "moderate" in emotionality by a group of subjects with characteristics similar to the subjects who participated in the investigation proper (college-age women). Furthermore, immediately following data collection, the subjects were asked to rate the degree of emotionality they experienced during performance of each of the four speaking activities. It is interesting to note that the initial speaking activity (First Topic/No Outline Task) received the highest average rating; however, this apparent difference was not statistically significant (at the .01 level). Nevertheless, the precise meaning of these ratings is not clear, in part because no formal definition of emotionality was provided. It could have been that emotionality ratings reflected the "strength" of conviction regarding opinions expressed about the topics under discussion (i.e., "Quality of education in the United States" and "The effect of television violence on children"), or they could have reflected feelings of performance anxiety, or some combination of these factors and perhaps others. Previous research has identified anxiety as a potential causal agent in the production of pauses (Goldman-Eisler, 1955; Lay & Paivio, 1969; Reynolds & Paivio, 1968; Rochester, 1973; Siegman & Pope, 1966).

Although filled pauses did not help explain differences in fluency-related measures, all of the present subjects produced filled pauses at least occasionally. It seems reasonable to assume that filled pauses, like their silent counterparts, represented observable indicators of cognitive-linguistic formulation (Siegman & Pope, 1966). This assumption was supported by the fact that filled pauses were commonly found at conceptual junctures, that is, points of transition from one idea to another. However, filled pauses also seemed to serve another function—that of "holding the floor"—particularly during performance of the Outline Task. Specifically, in some subjects, filled pauses were produced at moments when discussion of one subtopic had just been completed and the subject was apparently in the process of scanning the outline for cues regarding the next subtopic. The subjects who exhibited this type of pausing behavior tended to be those who generated outlines consisting of short "bullet" statements or key words, in contrast to those who tended to generate outlines containing more lengthy prose. Filled pauses produced in this context seemed to function as a signal that the subject planned to continue speaking and did not want to be interrupted (Maclay & Osgood, 1959).

Finally, it is also of interest to consider the pause-related behavior of the individual subjects studied. Each subject produced both silent pauses and filled pauses, at least occasionally. Regarding the former, although each subject produced both breath-hold and expiratory silent pauses, each exhibited a "preferred" type of silent pause. Specifically, for 17 of the 20 subjects, whichever type of silent pause predominated during the No-Outline Task also predominated during the Outline Task. Breath-hold pauses were predominant in 5 subjects and expiratory pauses in 12 subjects. Regarding filled pauses, subjects differed in the frequency with which they produced filled pauses; however, this was generally consistent across speaking activities. That is, subjects who produced filled pauses relatively frequently tended to do so for all activities, and the same was true for subjects who produced them relatively rarely.

Conclusions

This investigation has shown that the general mechanical behavior of the breathing apparatus is essentially unaffected by the cognitive-linguistic demands of the speaking task, at least for the types of tasks examined. Therefore, when attempting to characterize volumes of the lung, rib cage, and abdomen, or when inferring muscular mechanisms from such volumes, differences in task difficulty may not be a primary concern. However, fluency-related speech breathing behaviors are extremely sensitive to differences in cognitive-linguistic demands and thus should be carefully controlled.

Acknowledgments

This research was supported, in part, by Clinical Investigator Development Award DC-00030 and National Multipurpose Research and Training Center Grant DC-01409 from the National Institute on Deafness and Other Communication Disorders. The authors gratefully acknowledge the helpful comments of Merrill F. Garrett, Anthony B. DeFeo, and Carol A. Boliek on an earlier draft of this manuscript and the assistance of E. Fiona Bailey, Cynthia L. Johnson, and Christie L. Jenks. The authors also appreciate the thoughtful suggestions offered by the Associate Editor, Elaine T. Stathopoulos, and three anonymous reviewers.

References

Bless, D., & Miller, J. (1972, November). *Mechanical and linguistic factors influencing lung volumes in speech*. Paper presented at the American Speech and Hearing Association Convention, San Francisco.

Butterworth, B. (1980). Evidence from pauses in speech. In B. Butterworth (Ed.), *Language production, Vol. 1: Speech and talk*. London: Academic Press.

Conrad, B., Thalacker, S., & Schönle, P. (1983). Speech respiration as an indicator of integrative contextual processing. *Folia Phoniatrica, 35,* 220–225.

Flower, L. (1989). *Problem solving strategies for writing* (3rd ed.). Orlando, FL: Harcourt Brace Jovanovich, Inc.

GMG Scientific Inc. (1980). *Operation manual for linearized magnetometers*. Burlington, MA: GMG Scientific Inc.

Goldman-Eisler, F. (1955). Speech-breathing activity—A measure of tension and affect during interviews. *British Journal of Psychology, 29,* 53–63.

Goldman-Eisler, F. (1956). The determinants of the rate of speech output and their mutual relations. *Journal of Psychosomatic Research, 1,* 137–143.

Greene, J. (1984). Speech preparation processes and verbal fluency. *Human Communication Research, 11,* 61–84.

Greene, J., & Cappella, J. (1986). Cognition and talk: The relationship of semantic units to temporal patterns of fluency in spontaneous speech. *Language and Speech, 29,* 141–157.

Grosjean, F., & Collins, M. (1979). Breathing, pausing, and reading. *Phonetica, 36,* 98–114.

Henderson, A., Goldman-Eisler, F., & Skarbek, A. (1965). Temporal patterns of cognitive activity and breath control in speech. *Language and Speech, 8,* 236–242.

Hixon, T., Goldman, M., & Mead, J. (1973). Kinematics of the chest wall during speech production: Volume displacements of the rib cage, abdomen, and lung. *Journal of Speech and Hearing Research, 16,* 78–115.

Hixon, T., Mead, J., & Goldman, M. (1976). Dynamics of the chest wall during speech production: Function of the thorax, rib cage, diaphragm, and abdomen. *Journal of Speech and Hearing Research, 19,* 297–356.

Hodge, M., & Rochet, A. (1989). Characteristics of speech breathing in young women. *Journal of Speech and Hearing Research, 32,* 466–480.

Hoit, J., & Hixon, T. (1986). Body type and speech breathing. *Journal of Speech and Hearing Research, 29,* 313–324.

Hoit, J., & Hixon, T. (1987). Age and speech breathing. *Journal of Speech and Hearing Research, 30,* 351–366.

Hoit, J., Hixon, T., Altman, M., & Morgan, W. (1989). Speech breathing in women. *Journal of Speech and Hearing Research, 32,* 353–365.

Hoit, J., Hixon, T., Watson, P., & Morgan, W. (1990). Speech breathing in children and adolescents. *Journal of Speech and Hearing Research, 33,* 51–69.

Hoit, J., Plassman, B., Lansing, R., & Hixon, T. (1988). Abdominal muscle activity during speech production. *Journal of Applied Physiology, 65,* 2656–2664.

Knudson, R., Lebowitz, M., Holberg, C., & Burrows, B. (1983). Changes in the normal maximal expiratory flow-volume curve with growth and aging. *American Review of Respiratory Disease, 127,* 725–734.

Konno, K., & Mead, J. (1967). Measurement of the separate volume changes of rib cage and abdomen during breathing. *Journal of Applied Physiology, 22,* 407–422.

Lass, N., & Clegg, J. (1973). Comparative study of temporal characteristics of picture-elicited and topic-elicited speech. *Perceptual and Motor Skills, 36,* 995–998.

Lay, C., & Paivio, A. (1969). The effects of task difficulty and anxiety on hesitations in speech. *Canadian Journal of Behavioral Science, 1,* 25–37.

Levelt, W. (1989). *Speaking: From intention to articulation.* Cambridge, MA: MIT.

Maclay, H., & Osgood, C. (1959). Hesitation phenomena in spontaneous English speech. *Word, 15,* 19–44.

Miller, A. (1986). Prediction equations and "normal values." In A. Miller (Ed.), *Pulmonary function tests in clinical and occupational lung disease* (pp. 197–213). New York: Grune & Stratton.

Reynolds, A., & Paivio, A. (1968). Cognitive and emotional determinants of speech. *Canadian Journal of Psychology, 22,* 164–175.

Rochester, S. (1973). The significance of pauses in spontaneous speech. *Journal of Psycholinguistic Research, 2,* 51–81.

Russell, N., & Stathopoulos, E. (1988). Lung volume changes in children and adults during speech production. *Journal of Speech and Hearing Research, 31,* 146–155.

Shuy, W., & Fasold, R. (Eds.). (1973). *Language attitudes: Current trends and prospects*. Washington, DC: Georgetown University Press.

Siegman, A., & Pope, B. (1966). Ambiguity and verbal fluency in the TAT. *Journal of Consulting Psychology, 30,* 239–245.

Society of Actuaries and Association of Life Insurance Medical Directors of America (1980). *Build study 1979*. Chicago: Author.

Solomon, N., & Hixon, T. (1993). Speech breathing in Parkinson's disease. *Journal of Speech and Hearing Research, 36,* 294–310.

Stathopoulos, E., Hoit, J., Hixon, T., Watson, P., & Solomon, N. (1991). Respiratory and laryngeal function during whispering. *Journal of Speech and Hearing Research, 34,* 761–767.

Sugito, M., Ohyama, G., & Hirose, H. (1990). A preliminary study on pauses and breaths in reading speech materials. *Annual Bulletin of the Research Institute of Logopedics and Phoniatrics, 24,* 121–130.

Tannen, D. (1990). *You just don't understand: Men and women in conversation.* New York: Ballentine Books.

Tashkin, D., Clark, V., Coulson, A., Simmons, M., Bourque, L., Reems, C., Detels, R., Sayre, J., & Rokaw, S. (1984). The UCLA population studies of chronic obstructive respiratory disease. VIII. Effects of smoking cessation on lung function: A prospective study of a free-living population. *American Review of Respiratory Disease, 130,* 707–715.

Taylor, I. (1969). Content and structure in sentence production. *Journal of Verbal Learning and Verbal Behavior, 8,* 170–175.

Till, J., & Goff, A. (1986, November). *Task variables affecting temporal structure and respiratory patterns in speech.* Paper presented at the American Speech-Language-Hearing Association Convention, Detroit.

Webb, R., Williams, F., & Minifie, F. (1967). Effects of verbal decision behavior upon respiration during speech production. *Journal of Speech and Hearing Research, 10,* 49–56.

Winkworth, A., Davis, P., Adams, R., & Ellis, E. (1995). Breathing patterns during spontaneous speech. *Journal of Speech and Hearing Research, 38,* 124–144.

Winkworth, A., Davis, P., Ellis, E., & Adams, R. (1994). Variability and consistency in speech breathing during reading: Lung volumes, speech intensity, and linguistic factors. *Journal of Speech and Hearing Research, 37,* 535–556.

Received February 3, 1995
Accepted July 3, 1995

Contact author: Jeannette D. Hoit, PhD, Department of Speech and Hearing Sciences, University of Arizona, Tucson, AZ 85721. E-mail: jenjen@cnet.shs.arizona.edu