Effect of Speech Task on Intelligibility in Dysarthria: A Case Study of Parkinson's Disease

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Effect of Speech Task on Intelligibility in Dysarthria: A Case Study of Parkinson's Disease

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This study assessed intelligibility in a dysarthric patient with Parkinson's disease (PD) across five speech production tasks: spontaneous speech, repetition, reading, repeated singing, and spontaneous singing, using the same phrases for all but spontaneous singing. The results show that this speaker was significantly less intelligible when speaking spontaneously than in the other tasks. Acoustic analysis suggested that relative intensity and word duration were not independently linked to intelligibility, but dysfluencies (from perceptual analysis) and articulatory/resonance patterns (from acoustic records) were related to intelligibility in predictable ways. These data indicate that speech production task may be an important variable to consider during the evaluation of dysarthria. As speech production efficiency was found to vary with task in a patient with Parkinson's disease, these results can be related to recent models of basal ganglia function in motor performance.   © 2002 Elsevier Science (USA)

Key Words: intelligibility; dysarthria; Parkinson's; speech; reading; repetition; singing.

Parkinson's disease (PD) is caused by basal ganglia dysfunction and creates a movement disorder characterized by bradykinesia (slow movements), muscle rigidity, and resting tremor. Parkinson's disease often produces hypokinetic dysarthria, typified by imprecise articulation, prosodic abnormalities, disturbance of speech rate, and low vocal volume (Canter, 1965; Darley, Aronson, & Brown, 1975; Duffy, 1995; Netsell, Daniel, & Celesia, 1975; Weismer, 1984, 1997; Metter, 1985). The Mayo

Clinic characterization of hypokinetic dysarthria emphasizes, in rank order, mono-pitch, reduced stress, monoloudness, imprecise consonants, inappropriate silences, short rushes, harsh voice, continuous breathiness, pitch level disturbances, and variable rate (Darley et al., 1975, p. 193). Speech rate and loudness have been consistently described as abnormal in PD. Some patients with Parkinson's disease speak more slowly than controls and others more rapidly (e.g., Canter, 1963, 1965; Caligiuri, 1989; Darley et al., 1975; Adams, 1994). Although reduced loudness is not emphasized in the Mayo characterization or several other descriptions of Parkinsonian speech (e.g., Canter, 1963; Love, 1995) reduced volume is often observed clinically and has been described as a prominent, and even an initial, clinical feature of the disease (e.g., Darley & Spriestersbach, 1978; Logemann, Fisher, Boshes, & Blonsky, 1978).

The speech disturbance in PD is attributed to ''neuromuscular abnormalities in much of the speech musculature, usually related to restriction in the range or speed of movement patterns'' (Duffy, 1995, p. 173). Although there is considerable variability in movement and speech symptoms across patients (Metter & Hanson, 1986), for any individual patient, it is generally held that ''the motor control problems are present regardless of tasks or context'' (Yorkston, Beukelman, & Bell, 1988, p. 62) and the dysarthria is characterized by ''highly consistent articulatory errors'' (Yorkston et al., 1988, p. 66). Shames and Wiig (1990) also emphasize the consistency of deficits across speech tasks, stating that patients with dysarthria show ''very little difference in articulatory accuracy between automatic-reactive and volitional-purposive speech'' (p. 470). The assumption that the characteristic signs of dysarthria occur consistently across speaking conditions also underlies current assessment protocols, which alternately utilize reading or repetition in order to estimate overall speech intelligibility (Enderby, 1983; Yorkston & Beukelman, 1981).

Despite the traditional assumption that speech deficits are consistent in PD, there is some evidence that the signs of dysarthria vary across speech tasks. For instance, speaking loudly, which can be considered a special speaking task, has been shown to increase speech clarity (Duffy, 1995; Rosenbek & LaPointe, 1978). In fact, the improvement of speech with increased volume is so striking that Ramig and colleagues have developed a treatment program for Parkinson's dysarthria specifically designed to improve vocal volume (e.g., Ramig, Countryman, Thompson, & Horii, 1995; Dromey, Ramig, & Johnson, 1995). Delayed auditory feedback (Hanson & Metter, 1983) and slower (paced) speech, which, in a sense, are also different types of speaking tasks, have been shown to improve intelligibility (e.g., Hammen, Yorkston, & Minifie, 1994; Duffy, 1995; Ramig, 1992). In a study of accelerated speech following bilateral thalamic surgery in a patient with PD, Canter and Van Lancker (1985) observed that the patient was more intelligible to listeners when reading aloud than when speaking spontaneously. In this study, the spontaneous speech sample was obtained by having the subject describe his work, while the read sample was a selected paragraph (Rainbow Passage). In a study that compared sentences from the Assessment of Intelligibility of Dysarthric Speech (Yorkston & Beukelman, 1981) with spontaneous speech obtained by asking 20 dysarthric subjects of varying etiologies to answer ''general knowledge'' questions, Frearson (1985) also found that dysarthric speakers were more intelligible when reading aloud than when speaking spontaneously. Clinical observations suggest that patients with PD dysarthria are more intelligible when singing than speaking (C. Waters, personal communication, 1994).

Acoustic measures have also revealed correlations between dysarthria and speech task. Brown and Docherty (1995) compared several acoustic parameters in dysarthric

speakers (of variable etiology) while they read a phonetically balanced paragraph versus spoke spontaneously in a conversational setting. The study was designed to elicit spontaneous utterances that would be similar to the material previously read aloud. The reading condition was associated with longer vowel durations in some patients, but not in those with PD. The PD patients showed a different speech task difference—longer voice onset times in reading. Kent, Kent, Rosenbek, Vorperian, & Weismer (1997) investigated speech task differences for patients with cerebellar ataxia by comparing repetition with conversational speech. They reported that the dysarthric speakers produced longer syllable durations than the control group in sentence repetition, but not in conversation. They suggested that differences in motor programming and the ''linguistic cognitive processing'' between sentence repetition and conversation may explain the acoustic differences. Other researchers have noted that the relative rankings of deviant perceptual characteristics are not the same in syllable repetition as in reading for patients with dysarthria (Zeplin & Kent, 1996). Notably, none of these studies used the same phrases to directly compare speech tasks.

Thus, despite the traditional teaching that dysarthric features are consistent across types and contexts of speech production, there is some evidence of variable performance associated with speech production task. Yet there have been no direct, systematic comparisons of intelligibility and other speech measures across a range of task production conditions. The research presented here was undertaken to investigate the variability of speech performance in PD hypokinetic dysarthria by evaluating intelligibility across five speech production tasks: spontaneous speech, reading aloud, repetition, repeated singing, and spontaneous singing. The first three task conditions were selected to explore speaking tasks. The second two were based on clinical observations, and previous proposals that singing be used as a therapeutic technique (Cohen, 1992, 1994; Pacchetti et al., 2000). Repeated singing enabled us to make a direct comparison between singing with the other speech tasks containing the same linguistic material, while spontaneous singing allowed us to determine whether singing differed enough to be useful as a method of communication. A further goal of this research was to explore the relationship between intelligibility and selected perceptual and acoustic parameters.

METHOD

Speaker.   Speech samples were collected from BA, a 74-year-old retired professor and native speaker of English,[1] diagnosed with PD 18 years prior to this investigation. On the Hoehn and Yahr (1967) rating scale, he was at stage 2 (bilateral or midline involvement without impairment of balance). Medication dosage was 650 mg levodopa/carbidopa (Sinemet) per day. One of his primary symptoms was speech impairment. His spontaneous speech was characterized by monopitch, monoloudness, low vocal volume, prolongation and repetition of sounds and syllables, voice breaks, hypernasal resonance, and articulatory imprecision. He was very difficult to understand in conversation. Intelligibility was measured using the Assessment of Intelligibility of Dysarthric Speech (Yorkston & Beukelman, 1981), scored by transcription. The results revealed 46% intelligibility for single words, 68% intelligibility for sentences, a speaking rate of 137.5 words per minute, and an efficiency ratio of 0.49. BA had received short-term group speech therapy several years prior to this investigation. He had not received any professional training in singing.

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[1] BA was born in England and has lived in the United States for over 30 years. His speech still contains some British dialectal features. This fact was not considered problematic in this study for the following reasons: (1) the listeners, who were obtained from a large urban area (Los Angeles), were accustomed to hearing a wide variety of dialectal variation, (2) practice items to acclimate the listeners to the speaker's idiolect preceded the listening test, and (3) the comparison of interest was between speech tasks using identical phrase types which were all presented in the same idiolect.

He had not undergone any surgical procedures related to PD such as pallidotomy or thalamotomy. Hearing and vision were unimpaired by patient report and by observation: his vision was sufficient to read aloud without error and his hearing was adequate to converse and follow verbal commands without problem.

Stimulus development.   We obtained vocal production samples from BA in order to compare intelligibility of spontaneous speech, repetition, reading, and two different singing tasks, repeated and spontaneous singing. A tape recording of the subject's speech was made in a sound-attenuated booth onto a Marantz PMD 201 cassette recorder, with the subject speaking into a head-worn microphone maintaining a constant mouth-to-microphone distance of 2 inches. Microphone position (distance and angle from mouth) and the recording gain settings were identical across all recording events.

Through a conversation about his early life, we elicited a spontaneous speech sample. During this conversation, BA responded to many conversational prompts such as ''What type of work did your father do?'' and ''Tell me about your early schooling.'' While one author conversed with BA in the sound-attenuated booth, the other author sat outside the booth, listened to the conversation via head phones, and transcribed 30 of BA's consecutive utterances. BA was queried when portions of his speech were not intelligible to ensure an accurate transcription of his statements. His utterances ranged in length from 3 words (''mainly dairy farming'') to 15 words (''I grew up in a home which was a tiny cottage with a thatched roof''), with a mean length of 8.2 words. The 30 utterances were transcribed legibly in large print onto three sheets of paper, each sheet containing 10 of the 30 utterances (numbered 1–10). During this same session, these utterances were presented to him to elicit production in three other speech tasks: reading, repetition, and repeated singing. For each set of 10 utterances, the order of reading, repetition, and repeated singing was counterbalanced, such that BA produced each set of 10 in a different order (set 1: read–repeated–sung; set 2: repeated–sung–read; set 3: sung–read–repeated). To elicit reading, he was shown a sheet of numbered utterances, and asked to read each one aloud. To elicit repetition, each utterance was spoken by one of the authors with normal rate and articulation, and he was asked to repeat it verbatim. In the repeated singing condition, each utterance was sung to the subject, and he sang it back. For this condition, the words were intoned in melodic intervals of seconds and thirds forming an overall melodic contour for the utterance in a pitch range comfortable for the subject. For example, in the musical notation SOLFEGE, the utterance ''it's a small village'' was sung in the following melody: RE-RE-MI-DO-DO. No familiar melodies were used. In a separate session several weeks following the first session, using the same recording equipment, location, microphone placement, and recording gain setting, spontaneous singing was elicited. During this session, BA was asked to sing conversational responses. Both recording sessions took place approximately 60 min after BA had taken his medication; his medication appeared equally effective throughout the entirety of each session.

A set of stimuli was selected from the original 30 utterances (each elicited in four speech tasks). The stimuli were semantically coherent phrases, chosen to be as heterogeneous in theme as possible. Only those utterances with identifiable phonetic onsets and offsets, forming complete phrases or sentences, were selected as stimuli. The variability in phrase length and topic was maximized to limit linguistic, grammatical, and thematic redundancy. Because the conversation was about BA's childhood, family, and schooling, there were several instances of local place names (''hills of Somerset'') and repeated mention of certain words (e.g., ''father''), as well as rare or unusual usage (e.g., ''the webbing industry''). In selecting stimuli we eliminated local place names and rare terms, and minimized repetition of specific words. All stimuli were grammatical phrases or sentences between 2 and 6 words in length (mean length = 3.73 words, median = 3.5 words, mode = 3 words) and are listed in the Appendix. This process resulted in a set of 32 utterances, each spoken in four conditions (yielding 128 stimuli). An additional set of 8 utterances produced in spontaneous singing was added to the stimuli, yielding a total of 136 unique stimuli.

The stimuli were digitized using the Computerized Speech Lab (CSL) Model 4300B (Kay Elemetrics Corp.). The stimuli were sampled at 10,000 Hz using built-in antialiasing filters. Four listening tapes were made from the digitized samples. Each listening tape contained a different speech task version of each of the 32 utterances, plus the same eight exemplars of spontaneous singing. For example, all tapes contained the utterance ''it's a small village,'' but the spontaneous version was on tape 1, the repeated version on tape 2, the read version on tape 3, etc. Altogether, each tape contained a total of 8 spontaneously spoken, 8 read, 8 repeated, 8 sung as repetition, and 8 spontaneously sung utterances. The utterances types were in the same order on each tape, but the order of representative samples derived from each production task was random, not blocked. In order to acclimate the listeners to the task and to the speaker's voice and idiolect, each tape began with four practice items not included in the test material.

Listening task.   Subjects listened to 4 practice items and 40 test items, and transcribed portions of each stimulus onto blank lines on an answer sheet. Listeners were given immediate feedback on the practice items. For the test utterances, each answer sheet included 100 blanks, 20 per speech condition. The blanks (target words) were the same for each listening tape. As can be seen in the Appendix, for

most utterances one or more words in each stimulus item was included on the answer sheet, providing contextual support (i.e., creating a ''cloze'' procedure). This was done to achieve a listening task of moderate, rather than extreme, difficulty. To ensure that responses could not be predicted from the linguistic context provided on the answer sheets, 16 subjects attempted the cloze task from the written materials alone. The subjects performing the written version of the listening test were native speakers of English, free of neurological or psychiatric disorders and with adequate visual acuity to complete the task (determined by subject report). They ranged in age from 28 to 75, with a mean age of 45.9, and a mean education of 17.6 years. Of the total number of 1600 blanks filled in on the answer sheets, the subjects in the written-only condition correctly guessed a total 24 (1.5%) of the target items. This demonstrated that the contextual cues in the written material were not sufficient to bias the subjects' responses in the listening task. Identical answer sheets were used for all listening tapes, and therefore the same amount of contextual support was available for the utterances in each speaking condition. Listeners were told that they would be hearing a tape recording of a person with Parkinson's disease and their task was to write down what they heard on the answer sheet provided. A spoken number (recorded by one of the authors) preceded each stimulus item, and each item was separated by a 10-s interstimulus interval. Stimuli were heard only once.

Listeners. Sixty-four listeners participated by listening to one of the four tapes described above (16 listened to each tape). Their ages ranged from 23 to 78 years (mean 44 years); education ranged from 12 to 22 years (mean 18 years). All listeners were native speakers of English, free of neurological or psychiatric disorders, and with hearing and visual acuity adequate to perform the task, determined by their own report. Subjects were tested either individually or in small groups of 2 or 3 people. Stimulus tapes were played on a Marantz PMD201 in sound field via an external speaker (Fostex 6301B). The listeners determined a comfortable loudness level.

ANALYSES AND RESULTS

Intelligibility

To determine intelligibility of the utterances in each speech task, correctly transcribed words were counted. Credit was given for singular/plural listening errors (e.g., if the subject said ''cat'' and the listener wrote ''cats,'' it was scored as correct), but for no other morphologically related words. Contractions were counted as one word. Comparisons were then made between the number of words correctly identified on the four listening tapes and the five speech tasks. Using a simple one-way ANOVA, with 40 utterances per tape as the dependent variable, comparison of the four listening tapes revealed no difference in overall level of difficulty ($F(3, 156) < 1$). Since all four tapes were similar in number of errors, the data from the four tapes were combined for all subsequent analyses. Figure 1 displays mean percentage intelligibility across five speaking tasks and four listening tapes.

Overall, listeners were able to understand 29% of the spontaneous utterances, 78% of read utterances, 79% of repeated spoken, 80% of repeated sung expressions, and 88% of the spontaneously sung utterances. In a within-subjects design, a one-way ANOVA examining speech task with percentage intelligibility of each utterance as the dependent variable was highly significant: ($F(4, 155) = 33.62$, $p = .0001$). Post hoc t-test comparisons showed that (1) spontaneous speech was significantly different from each other task ($p < .05$), and (2) the other four speech tasks were not significantly different from one another.

Acoustic and Perceptual Measures

Four analyses explored the relationship between intelligibility and the acoustic characteristics of the stimuli: relative intensity, word duration, dysfluency (as measures of speech timing), and acoustic qualities as seen in spectrograms. All analyses used the digitized samples that made up the stimuli in the listening tapes.
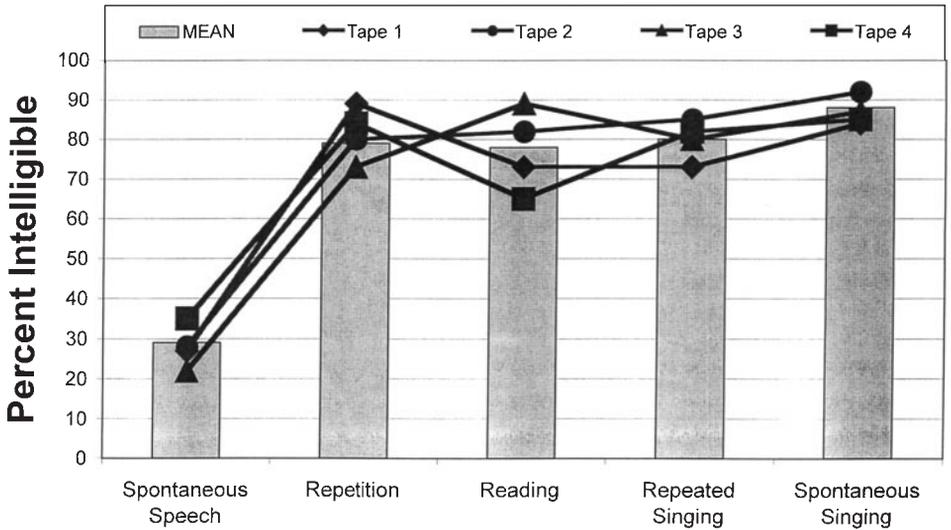
FIG. 1. Percentage intelligibility of a patient with Parkinson's disease across five speech tasks and four stimulus tapes.

Loudness. To establish whether loudness contributed significantly to the intelligibility of these utterances, we compared relative intensity across speech tasks and across items. The measurement of relative intensity for each stimulus item was the root mean square (RMS) in decibels (dB) as calculated by the Kay CSL. A factorial ANOVA comparing the mean amplitude of utterances in each speech task showed a significant effect of task ($F(4, 131) = 2.99$, p $= .02$). Post hoc comparisons revealed that spontaneous singing was louder than the other tasks ($p < .05$) (see Fig. 2). No other comparisons were significant. To evaluate the association of loudness to intelli-
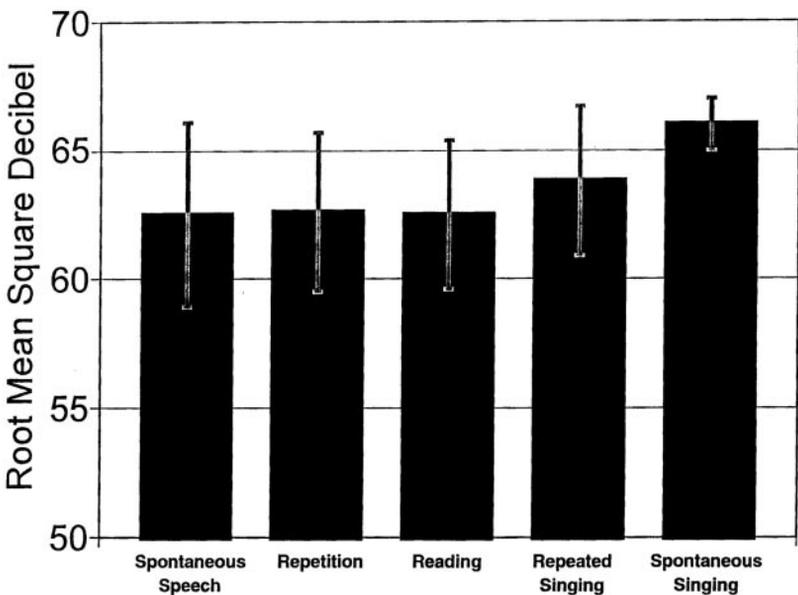

FIG. 2. Average relative loudness measured in root mean square decibels (RMS dB) of utterances produced in five speech tasks. The vertical bars indicate standard error.
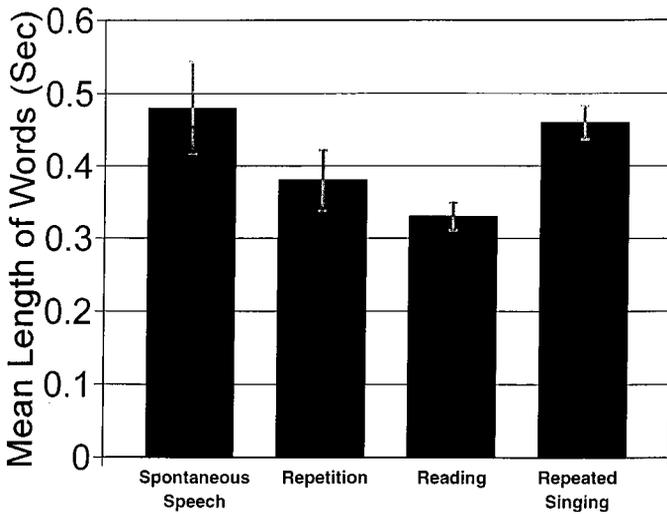
FIG. 3. Mean word length and standard error for utterances produced in four speech tasks.

gibility across individual items, the mean intelligibility score of each item was calculated and a correlation between this figure and the RMS dB for each item was computed. RMS dB values in our sample were not correlated with intelligibility across all items ($r = .14$, $p > .05$), or across items within any of the speech tasks individually, suggesting that volume alone was not a potent variable affecting intelligibility in these data.

Word duration. Mean duration per word (utterance length divided by number of words) was used to determine if words spoken in any task were either longer (i.e., spoken more slowly) or shorter (i.e., spoken more quickly) than in the other speech tasks. (Spontaneously sung items were not included in this analysis because they contained different words than the utterances in the other four conditions.) An ANOVA comparing mean duration per word was just short of .05 level of significance ($F(3, 124) = 2.58$; $p = .057$). The mean duration of phrases in the spontaneous speech condition was slightly longer than the other speech tasks (see Fig. 3). No post hoc comparisons between the speech tasks were significant. Therefore, although there is a hint that spontaneously produced words are somewhat longer (i.e., produced more slowly) than the same words produced in other tasks, the difference is slight, and is likely due to a combination of factors rather than simply due to slower articulation (e.g., see discussion below regarding the role of dysfluency in intelligibility).

A second analysis of word duration examined the relationship between average word duration and intelligibility across all items, using a Pearson correlational analysis. This comparison revealed a nonsignificant correlation ($r = .035$, $p = .66$). The same pattern was seen for each speech task individually. These results indicate that mean word duration, as one index of speech timing, does not account for intelligibility differences between speech modes or between items.

Dysfluencies. To evaluate the contribution of speech dysfluencies to intelligibility, two raters reviewed the listening tapes independently (one of the authors and a speech pathology graduate student blind to the purpose and nature of the study). Each rater counted the number of perceived dysfluencies, operationally defined as abnormally long (>1 s) and/or inappropriately placed (e.g., midword) pauses, sound repetitions, and sound prolongations. Reliability between the two authors was 94% (kappa $= 0.834$, $p < .001$), with all disagreements resolved through discussion.
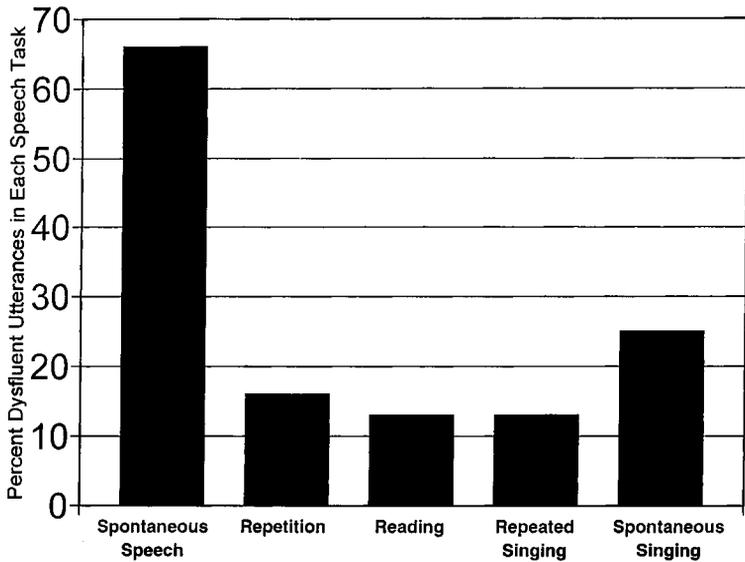
FIG. 4. Percentage of utterances in each of five speech tasks that contained obvious dysfluencies, including sound, syllable, and word repetition as well as sound prolongation.

Thirty-six percent of the utterances contained perceived dysfluencies. Dysfluencies were not limited to the beginning of utterances, as 40% of the dysfluencies were midphrase. The percentage of utterances containing dysfluencies in each speech task is shown in Fig. 4. There was a significantly greater number (68%) of dysfluencies in the spontaneous items than in the other speech tasks ($\chi^2(4) = 36.7$, $p < .001$).

Spectrographic analysis. Using a rating system similar to that developed to characterize hoarseness by Yanagihara (1967a, 1967b), a qualitative measure of spectrograms was undertaken to determine whether there were acoustic differences between the production tasks. A wide-band spectrogram of each digitized stimulus was generated using consistently set parameters on the Kay Computerized Speech Lab (CSL) Model 4300B. Spectrograms were printed out for each of the 32 utterance types in the four production tasks. Each spectrogram was rated in terms of ''goodness,'' ranging from 1 (good) to 4 (poor) by the authors, independently. To perform the ratings, the four spectrograms for each utterance (same content, different speech tasks) were laid out in a random left–right sequence. The authors (both trained in spectrographic analysis at the UCLA Phonetics Laboratory) were blind to the speech production task but did consider the linguistic content of the target item. Spectrograms were rated ''good'' (1) if formants and consonant transitions were shown with coherence and clarity; acoustic material was rated ''poor'' (4) if formants were incoherent or smeared, and consonant transitions were notably lengthened, scattered, and otherwise not well-formed. Each rater independently scored each spectrogram with a unique number from 1 to 4 thereby creating a rank ordering from best to worst for each set of four. Sample spectrograms are shown in Fig. 5.

Interrater agreement was compared for each item. Most disagreements were an inversion of the two midposition rankings (2 and 3). Considering each of the 128 spectrograms individually, 63% received the same ranking by both judges (kappa = 0.51, $p < .001$). The highest agreement (81%) was seen for rating 4. Considering the 32 sets, each containing four spectrograms, 14 sets (44%) were ranked identically—each of the four spectrograms in these sets received the same ranking by both judges. This level of agreement is far above what would be expected by chance.
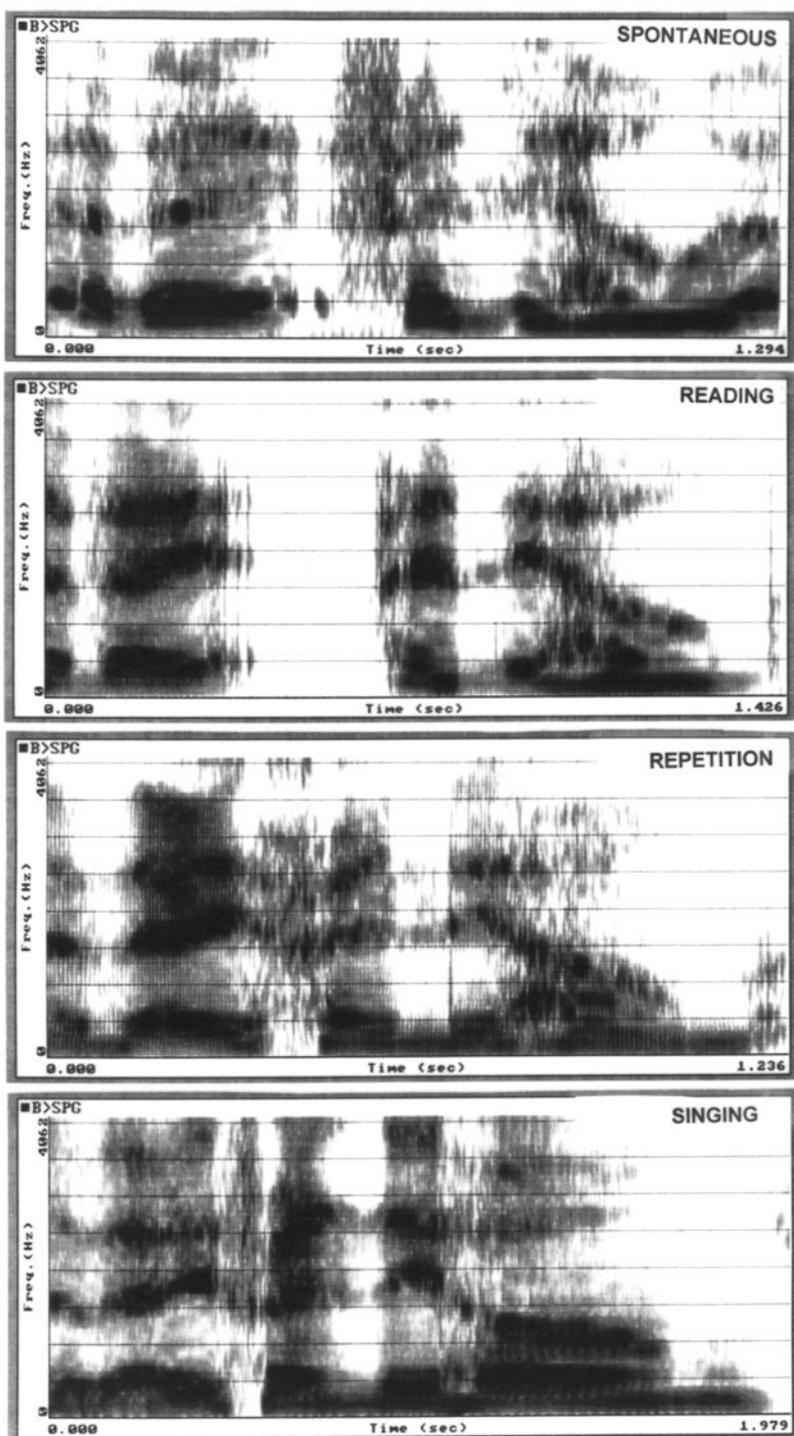
FIG. 5. Spectrograms of a dysarthric speaker producing the phrase ''a very friendly home'' in four speech tasks. Note the poorly defined formant structure in spontaneous speech compared with the other three tasks.
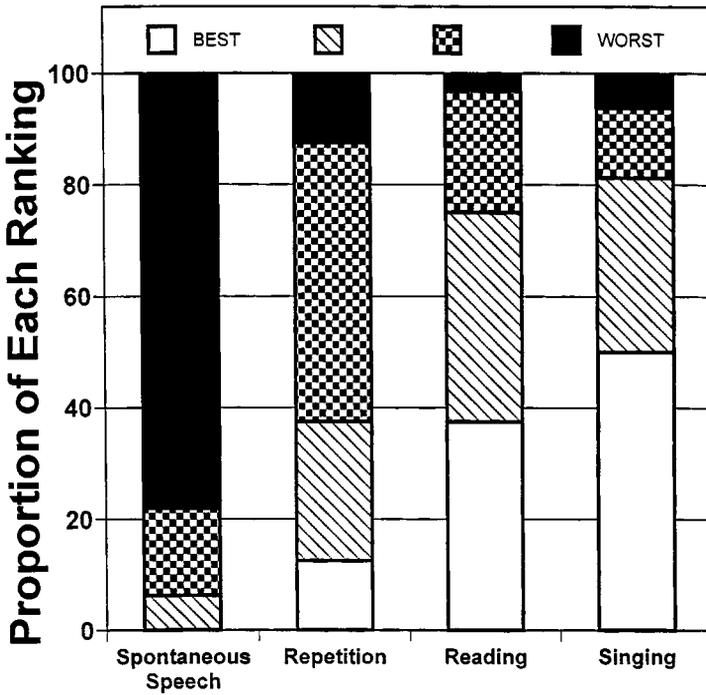
FIG. 6. Proportion of utterances in each speech task that received each spectrographic clarity rating.

The combinatorial possibilities of a single sequence of four items is four factorial or 24. That is, a given rank order of four items would occur by chance one in 24 times, or on 4.2% of occurrences. Therefore the possibility that two independent judges would assign the identical rank order to the four items in any array by chance is even smaller. The interrater agreement on 44% of the four-item arrays is therefore is at least 10 times the number expected by chance, demonstrating that the acoustic record can be used to clearly distinguish among these four speech modes. All ranking disagreements were resolved by discussion and the resulting data are presented in Fig. 6.

Figure 6 shows the relationship of the spectrographic ratings to speech task. It can be seen that the ratings are associated with particular speech tasks, as confirmed by chi-square results ($\chi^2(3) = 60.6$, $p < .001$). The spontaneous speech productions earned the poorest spectrographic ranking (4) in nearly 80% of the utterances. The spectrograms rated as good (1) were associated most often with singing (50%), followed by reading (36%) and then repetition (13%), while spontaneous speech exemplars received no 1 rankings. A Pearson's correlational analysis comparing spectrographic rankings with percentage intelligibility for individual items was significant ($r = -.41$, $p = .0001$), indicating that better rankings were associated with greater intelligibility.

DISCUSSION

This study explored the effect of speech production task on intelligibility for one dysarthric speaker. There was a significant difference between poor (29%) intelligibility of spontaneous speech compared with better (78–88%) intelligibility in reading, repeating, and repeated singing. Relative intensity and word duration by themselves

were not correlated with intelligibility. Dysfluencies and spectrographic patterns were significantly associated with intelligibility in predictable ways: the least intelligible productions contained more dysfluencies as well as greater spectrographic evidence of abnormal voice, articulation, and resonance.

It is an expected outcome that the spectrographic ratings captured information related to intelligibility. Normal voicing, articulation, and oral–nasal resonance produce smooth, well-defined formant structures with marked boundaries between consonant (aperiodic) and vowel (harmonic) segments (e.g., Kent & Read, 1992; Ladefoged, 1975; Baken, 1987). Abnormal phonatory patterns are seen as formant distortion and high frequency noise (Laver, 1980); abnormal articulation and resonance patterns are seen as poorly defined formants and abnormal formant transitions (Forrest, Weismer, & Turner, 1989; Kent et al., 1997; Weismer & Martin, 1992). In a former extensive study, a major category in the correlation between perceptual and acoustic features in PD speech was laryngeal control, accounting for several perceptual ratings as well as prominent noise patterns on spectrograms (Ludlow & Bassich, 1984).

One explanation that might be proposed for our main finding—that speech task affects intelligibility—involves a possible role of conscious processing. Indeed, as mentioned above, patients with PD can improve their speech with techniques which consciously slow them down (e.g., Hammen, Yorkston, & Beukelman, 1988) or with specific instructions such as to ''think loud'' (e.g., Rosenbek & LaPointe, 1978; Ramig et al., 1995). However, in this study no explicit instructions were given regarding speech or vocal production per se. The patient was only asked to read aloud, to repeat, or to sing. Therefore, any alternate motor control system that aided vocal performance was automatically engaged by the production task itself, not through explicit or conscious processes.

There are identifiable differences between the production tasks that may help explain these results, when related to models of basal ganglia function in motor behavior (Saint-Cyr, Taylor, & Nicholson, 1995), and clinical observations in PD. There is a well-established clinical literature that demonstrates better movement when initiation requirements are minimized or an external model is provided. Patients with PD who have difficulty initiating gait, once started, can often walk quite well. Movement improves with the provision of external cues, including auditory cues such as marching music, or visual stimuli, such as lines or raised strips on the floor (Martin, 1967; Burleigh-Jacobs, Horak, Nutt & Obeso, 1997; Cunnington, Iansek, & Bradshaw, 1999). While these observations have been made mainly in musculoskeletal limb movements, studies suggest that this same neurological dysfunction also underlies articulatory gestures (Ho, Bradshaw, Cunnington, Phillips, & Iansek, 1998). In the reading, repetition, and repeated-singing tasks reported here, external exemplars (or models), written or spoken, were provided, in contrast to the spontaneous condition. These external templates for vocal production may reduce the demand on internal cerebral resources for the motor behavior.

Although earlier neurological conceptions depicted the basal ganglia as essentially a relay system for cortical commands, much more is now known about the complex, interactional systems which control and manage movement (Brodal, 1981). Evidence that the basal ganglia executes detailed planning, initiation, and monitoring of movements, using sensory feedback systems, and in concert with other cerebral motor systems, comes from various studies of behavioral–motor function (Cummings, 1993; Atchison, Thompson, Frackowiak, & Marsden, 1993; Gassler, 1978; Georgiou et al., 1993; Marsden, 1982; Taylor & Saint-Cyr, 1992). In Baev's (1995) formulation, the dopaminergic system of the basal ganglia is engaged in ongoing matching of the predicted with the actual afferent flow coming from the motor gesture. Ac-

cording to Baev, the deficit in PD may be viewed as resulting from a dysfunction of this matching, or modeling, process. Other studies lead to the conclusion that PD involves an impaired ability to organize a motor plan (Beneke, Rothwell, Dick, Day, & Marsden, 1987). Studies of specific speech gestures have shown incoordination of vocal structures rather than global bradykinesia, supporting the notion of impaired ''higher'' motor planning in the disability as well as ongoing monitoring (Connor, Abbs, Cole, & Gracco, 1989; Gracco & Abbs, 1987). In studies of limb movements, errors in steps and stages of the motor program reflecting a deficient monitoring process have been observed (Weiss et al., 1997). Studies by Georgiou et al. (1994), using an illuminated pathway, noted that PD patients were negatively affected by reduction of the external cues. They, too, conclude that the normal basal ganglia generates internal cues for the beginnings and sequential portions of a movement gesture. These findings lead us to suggest that in our study, the spontaneous speech condition results in less efficient speech because in that condition, the dysfunctional basal ganglia is lacking an adequate, internally generated, model. In contrast, the reading and repetition conditions may benefit from the presence of the externally provided model, which provides an aid to planning, initiating, and monitoring of the speech gesture. Our data are consistent with the theoretical models of basal ganglia function and the clinical observations, insofar as better speech performance appeared when external models were available. We suggest that these external spoken or written models reduce the demands placed on the basal ganglia (and other motor behavior structures) in various ways, as yet poorly understood, in the planning, initiating, and executing of the vocal motor gesture.

However, these factors do not satisfactorily account for our results of improved intelligibility in spontaneous singing. This task required the speaker to generate an overall motor plan to the same extent as spontaneous speech. The basis for better intelligibility in the spontaneous singing task may be different than in the other tasks. For instance, singing is generally accompanied by increased respiration, which is in turn associated with increased speech volume and articulatory clarity. Another characteristic of singing is continuous pitch contour, which may reduce the demand for initiation of internal sequences, and therefore help to maintain ongoing movement. It may be that a combination of increased respiratory support and planning larger units (i.e., pitch contours) improves speech production as much as an overt model, but in a different way. In addition, observations of aphasic patients and stutterers, who usually can sing better than they can speak, suggest that singing and speech may be controlled by different brain mechanisms (Albert, Sparks, & Helm, 1973; Andrews, Howie, Dozsa, & Guitar, 1982; Belin et al., 1996; Helm-Estabrooks, 1983; Naeser & Helm-Estabrooks, 1985; Gordon & Bogen, 1981; Graves & Landis, 1985; Glover, Kalinowski, Rastatter, & Stuart, 1986). The demonstration of over 50% greater intelligibility in reading, repetition, and (repeated and spontaneous) singing compared to spontaneous speech in this single case study of a PD patient suggests that vocal production task may be an important factor in speech performance. Methods for assessing intelligibility often combine speech tasks (e.g., repetition or reading) (e.g., Yorkston & Beukelman, 1981). As was reported by Frearson in 1985, our data indicate that methods that use repetition and reading to assess intelligibility may overestimate conversational intelligibility in some patients and therefore lead to inadequate understanding of their actual communicative function.

It is appropriate to emphasize the limitations of an individual case study such as this. Future research with a larger sample of dysarthric speakers will be needed to investigate the effects of speech task on intelligibility, replicate our finding for spontaneous speech, and refine the subtler differences that may exist between reading, repetition, and singing.

APPENDIX: STIMULUS ITEMS FOR THE INTELLIGIBILITY TEST

Each italicized word was presented as a separate blank line on the answer sheet. Subjects were asked to fill in each blank. A–D are practice items; 1–40 are test items.

A: he also trained as a gardener
B: in addition to that *work*
C: in the *west* of *England*
D: *first* one in the *village*

1. it's a small *village*
2. *horse and cart*
3. he *came* to *England*
4. there are *ministers*
5. in the *church*
6. I wasn't *allowed to go*
7. *elementary school*
8. and it had a *little pantry*
9. another *industry*
10. I *enjoyed high school very much*
11. *famous American poet*
12. *ships* were *made* there
13. *there was* a *spiral staircase*
14. *my father*
15. a *very friendly home*
16. *villages don't have enough money*
17. *one* was *all he could take*
18. in the *back garden*
19. each *county* was *responsible*
20. *educational program*
21. what we call *public schools*
22. *then I went* to *high school*
23. *we* had *running water*
24. a *small village*
25. a *small town nearby*
26. the *industry*
27. the *last of the cottage industries*
28. *in the neighborhood*
29. the *cats*
30. this was *grammar school*
31. *mainly dairy farming*
32. I *grew up*
33. of *my life*
34. a *tiny cottage*
35. *my father's occupation*
36. a *thatched roof*
37. *tropical plants*
38. he *left* the webbing *industry*
39. very *small*
40. *move around* the *country*

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