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THE USE OF A DUAL-TASK PARADIGM FOR ASSESSING SPEECH INTELLIGIBILITY IN CLIENTS WITH PARKINSON DISEASE

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Abstract

Differences in the clinical and ecological manifestations of reduced intelligibility for individuals with dysarthria related to Parkinson disease (PD) have been reported in the literature. The current study explored whether a dual-task paradigm could be used during intelligibility testing to collect speech samples that were representative of functional performance. Intelligibility was calculated for four speakers with PD and four age-matched controls (CG) based on single-word, sentences, and monologue tasks recorded in single-and dual-task conditions and a spontaneous speech sample. In the dual-task condition, speakers produced the target speech sample and performed a simultaneous motor task, turning a nut on a bolt. No significant differences in intelligibility were found for the CG. For speakers with PD, differences between conditions were statistically significant for all speech tasks. Intelligibility scores in the dual-task condition were lower, with variability between tasks and speakers noted. There was a significant difference between scores for the monologue in the single-task condition and the spontaneous sample; however, there was no significant difference between the monologue in the dual-task condition and the spontaneous sample. Findings suggest that including a simple motor task during a clinical assessment may help elicit speech samples that are representative of a speaker's typical speech production.

Introduction

Speech intelligibility is an important construct in the assessment and management of clients with dysarthria. Clinically, intelligibility scores are used as an index of functional limitation, as a measure of severity of the speech disorder, as a guide for the treatment planning and to document and monitor change during or after remediation (Yorkston, Beukelman, Strand & Bell, 1999). Important decisions related to termination of treatment are often based, at least in part, on intelligibility scores. Because critical clinical decisions are based on intelligibility scores, the accuracy of these measures is of the utmost importance. Large differences in speech produced in a clinical or laboratory setting versus informal spontaneous situations have been reported anecdotally by clinicians as well as in the literature for speakers with Parkinson disease (PD), (Sarno, 1968; Weismer 1984; and Keintz, Bunton, and Hoit, 2007). Weismer (1984), for example, reported that speakers with PD were quite intelligible when producing experimental sentences, but were significantly less intelligible during spontaneous speech. While differences in speech produced in these settings have not been well quantified, for clinicians and researchers who wish to study speech production deficits

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associated with PD, potential differences in clinical and ecological manifestations of the dysarthria are problematic in terms of both understanding the impairment and clinical intervention.

Speech production and its resulting speech intelligibility has been shown to be influenced by speech material, physical setting, and motivation (Hustad & Weismer, 2007). During assessment, clinicians use a number of different speech tasks in an attempt to get a sense of a speaker's production abilities. It has been questioned, however, whether a direct relation exists between intelligibility measured under highly controlled conditions and more realistic conditions (i.e., spontaneous speech) (Kent, Weismer, Kent & Rosenbek, 1989). In a clinical setting, there are likely a number of subtle cues related to a speaker's motivation and the environment that may increase a speaker's attention to the task of speech production and thus affect their behavior. For example, in a clinic or research laboratory setting, speakers are keenly aware that the clinician is scrutinizing their speech production. The presence of recording and other testing equipment may also change the execution of the task (Aronson, 1990). This increased attention may lead to improved performance in production of individual phonemes, suprasegmental variables, increased amplitude of the speech signal, and possibly changes in the complexity of the message (e.g., the topic being discussed or preceding utterances), as well as nonverbal signals (e.g., gestures, postures, and facial expressions). Combined, these changes may result in higher speech intelligibility scores that are not representative of a speaker's typical production. Thus, a clinical assessment may create an unrealistic speaking situation where the speaker focuses all of their attention on a single task, speech production.

Everyday communication, on the other hand, can be considered a type of divided attention task where speakers are frequently required to coordinate the demands of message formulation and speech production with other daily activities such as driving, walking, preparing a meal, or watching television. In these situations, multiple stimuli compete for attentional resources (Dromey & Benson, 2003; Murray, 1999). Including a secondary task during intelligibility testing to divert some of a speaker's attention away from the primary task may be a way to create a more natural environment that will result in behaviors that are more representative of typical abilities. Performing two tasks simultaneously is an experimental procedure commonly referred to as a dual-task paradigm.

Dual-task paradigms have been widely used in research settings to examine the effects of divided attention on performance. The underlying assumption is that if attention is divided between two tasks performed simultaneously then performance on one or both will be negatively affected (Kahneman, 1973; Wickens, 1984). Several different models of attention have been used to explain changes in performance between single- and dual-task conditions. While a detailed review of these models is beyond the scope of this paper and can be found elsewhere (Allport; 1993; Murray, 1999; Navon & Miller, 2002; Shuster, 2004; Band, Jolicoeur, Akyurek, & Memelink, 2006) a brief overview of the two main views is warranted to understand why performance on dual-tasks may be different from performance on a single-task. One view of attention models the system as capacity-limited, where there is a fixed pool of attentional resources, and although the resources are limited, they can be flexibly and simultaneously allocated toward one or more activities (Moray, 1967; Kahneman, 1973; Navon & Miller, 2002; Wickens, 1984, 1989). The amount of attention directed toward a specific task relates to the its demands with factors such as novelty of the task, intent to attend to a specific input, or arousal level being key factors. Failure on a task can result from a misdirection of resources or inefficiency in the allocation of resources. A second view suggests that the brain processes stimuli serially. If multiple tasks require processing concurrently, a ‘bottleneck’ arises and completion of one task must wait or suffer (Pashler, 1984, 1990, 1994a, b). In other words, conflicts among multiple tasks are related to time-sharing as opposed to the sharing of resources suggested in the first view. Considerable debate exists with regard to both of these models and performance on different types of dual-task paradigms has been used as evidence for the different models (Band et al., 2006).

The majority of the research using dual-task paradigms has evaluated performance on motor tasks that were executed concurrently with secondary tasks that varied in modality and complexity (Chang & Hammond, 1987; LaBarba, Bowers, Kingsberg, Freeman, 1987; McLeod, 1977; Parush, 2005; Seth-Smith, Ashton, & McFarland, 1989; Simon & Sussman, 1987). In contrast, studies where changes in speech production were of primary interest have been limited to use of motor based secondary tasks because of concerns about single modality interference (i.e., two tasks competing for the same resources such as performance of mental arithmetic and verb generation tasks simultaneously). Motor tasks reported in the literature range from simple manual tapping to complex visual tracking or object assembly tasks (Bosshardt, Ballmer, de Nil, 2002; Dromey & Benson, 2003; Ho, Iansek & Bradshaw, 2002; Jou & Harris, 1992; Oomen & Postma, 2001). Changes reported in speech production have been shown to be related to the type of secondary task used and have included increases in the number of self-corrections in articulation, frequency of word deletion (Jou & Harris, 1992), word shadowing errors (Elliot, Weeks, Lindley, & Jones, 1986), and changes in pause location and structure (Oomen & Postma, 2001). Others have reported changes in speech rate (LaBarba et al., 1987), speech intensity (Ho et al., 2002), and labial kinematics (Dromey & Benson, 2003; Kleinow & Smith, 2000). All of the studies cited above have used healthy subjects.

It might seem reason able to assume that individuals with neuromotor diseases would perform more poorly on dual-tasks compared to healthy subjects. It has been hypothesized that differences in performance could be related to the reduced availability of attentional resources (Hallett & Khoshbin, 1980; Iansek, Bradshaw, Phillips, Cunnington, & Morris, 1995; Marsden, 1982). There is only a single study examining the effects of a dual-task on speech production in a clinical population. Ho et al. (2002) investigated how a visual guided manual tracking task affected speech production during number counting and during a conversation for speakers with PD and for speakers in an age-matched control group. Findings showed a slight trend of reduced mean intensity and a delay in initiation of counting sequences between conditions for the control group, but differences were not statistically significant. For participants with PD, there was an indication that the motor distractor task negatively affected speech production. A statistically significant decrease in speech intensity and increases in initiation time and pause time were reported. Ho et al. concluded that in the dual-task situation speakers with PD were not able to divide attention optimally between the two tasks and performance on both tasks declined, although more significantly on the speech task compared to the motor task. They reported that when participants focused their attention on the visual task typical Parkinsonian speech deficits became more pronounced.

Differences in the clinical and ecological manifestations of dysarthria for speakers with PD along with evidence in the literature that including a secondary task may limit some of these changes, provides a rationale for exploring use of a dual-task paradigm as a clinical technique to obtain a measure of speech intelligibility that may be more representative of a speaker's functional abilities. In general, studies of dual-task performance suggest that if one of the tasks is novel, complex, speeded, or visually guided it has a more negative effect on the other task (Li, Lindenberger, Fueund, & Baltes, 2001; Lindenberger, Marsiske, & Baltes, 2000; Morris, Iansek, Matyas, & Summers, 1996). For motor tasks in particular, it has been reported that greater interference results from activities where the dominant hand was engaged as compared to the non-dominant (Feyereisen, 1997; Friedman, Polson, & Dafoe, 1988). Because the task of spontaneous speech production is quite complex, involving a number of linguistic and cognitive processes, it was desirable to find a secondary task that would not interfere with these demands or have overly negative effects on speech intelligibility. Ideally, the motor task used as a secondary task would be matched to a speaker's typical behaviors. For example, if a women knits while she converses with a partner this task could be incorporated into a clinical assessment and perhaps treatment. Identifying a typical behavior would require a clinician to have contact with a client prior to assessment and this may not be feasible in many cases.

As a preliminary study of the effects of a secondary motor task on speech production for speakers with PD, a simple task of turning a nut on a bolt was designed. This task involved activity of the speaker's dominant hand, was continuous and somewhat repetitive to minimize difficulty with task initiation reported frequently for individuals with PD (Benecke et al., 1987). In addition, the speakers hands were beneath a black cloak so the task would not be visually guided.

The purpose of the present study was to compare speech intelligibility scores based on a number of different speech tasks in single- and dual-task conditions for speakers with PD and an age-matched control group. The hypothesis was that speech intelligibility measured in the dual-task condition would be lower than in the single-task condition for the PD group. No differences were expected for the control group. As a measure of functional speech performance, intelligibility was also calculated based on a spontaneous speech sample where the speaker did not know he/she was being recorded.

Method

Procedures were approved by the Institutional Review Board at the University of Arizona. Informed consent was obtained in all cases.

Speakers

Eight speakers participated in this study, four diagnosed with PD and four with no history of neurologic disease who served as a control group (CG). Speakers were between the ages of 62 and 71 years (Mean =67.3 years, SD=2.4 years). Speakers in the CG reported no history of neurologic disease, respiratory impairment, or speech and language impairment. For speakers with PD, a medical diagnosis was required, however, there were no explicit criteria regarding disease stage, duration, or manifestation. A neurologist classified all four speakers at Hoehn-Yahr stage 3. All speakers were judged to have hypokinetic dysarthria based on a clinical evaluation performed by an experienced speech-language pathologist who was not familiar with their medical diagnosis. This dysarthria type is consistent with a diagnosis of PD. Speakers with PD were stabilized on anti-Parkinson medications and did not demonstrate drug-induced dyskinesia. Speakers were recorded one to two hours after receiving their medication for PD.

A short battery of screening measures was administered to all potential participants (i.e., both PD and control group). To be eligible for participation, speakers needed to: a) have English as their first language, b) pass a hearing screening at 40dB HL for frequencies of 0.5, 1, 2, and 4.0 KHz bilaterally (Morrell, Gordon-Salant, Pearson, Brant & Fozard, 1996), and c) report no history of taking drugs known to produce oromotor dyskinesia (other than those currently being taken in association with PD). The Mini-Mental test (Folstein, Folstein & McHugh, 1975) was administered as a screen for dementia. All speakers had scores of at least 26/30 on this instrument. The Edinburgh handedness inventory was used to determine each speaker's handedness (Oldfield, 1971). All speakers were found to be right-handed.

Listeners

Ninety-six listeners participated in the present study. Listeners were recruited from the university community, and met the following criteria: a) between the ages of 18-50 years, b) no experience with speakers with dysarthria and, c) able to pass a hearing screening at 25 dB HL for frequencies of 0.5, 1, 2, and 4.0 KHz bilaterally (American Speech-Language-Hearing Association, 1997).

Speech Tasks

Three types of speech samples were recorded from each of the speakers: a) a set of 71 monosyllabic words taken from the Kent et al. (1989) intelligibility test, b) 60 low predictability sentences taken from the Hearing in Noise Test (HINT; Kalikow, Stevens & Elliot, 1977); and c) a monologue initiated by an investigator. The word and sentence tasks were elicited by having the speaker read the material from an index card. To elicit the monologue each speaker was asked to talk about a recent vacation. Monologues ranged in length from three to four minutes. These speech tasks were performed under two conditions, the first was a single-task condition where the speaker just spoke and the second was a dual-task conditions that included performing a motor task while speaking. Speech task and condition order were counterbalanced across speakers so that the dual-task condition did not cluster at the beginning or end of the session resulting in an inadvertent order effect. All speech samples were recorded on DAT tape (Tascam DA-P1) with a head mount microphone (Crown CM-311A) placed 3.5cm in front of the speaker's mouth. The speech samples were then digitized and stored in CSpeech (filter cutoff 9.8 KHz, sampling rate=22.1 KHz) (Milenkovic, 2002). Prior to recording, a 90dB calibration tone was recorded for use in calculating sound pressure level.

In addition to the speech tasks listed above, a two to three minute spontaneous speech sample was recorded from each speaker. This sample was elicited without the speaker's specific knowledge that he/she was being recorded. Prior to the session, the investigator asked each speaker's spouse to identify a conversational topic that would elicit an adequate speech sample. Topics typically described a recent event in the speaker's life. The spontaneous speech sample was the first speech sample recorded from each speaker. When the speaker came into the laboratory, they were seated comfortably in a chair, a written copy of the consent form was presented and a brief description of the experiment was given orally. After speakers were consented, the experimenter indicated that she needed to set up some equipment. During this time, the investigator initiated a conversation with the speaker. Unbeknownst to the speaker their speech was being recorded using the omni-directional condenser lavalier microphone (Audio-Technica, MT830R), which had been placed on the table approximately two feet in front of the speaker. Following recording of the spontaneous speech sample, the investigator switched microphones and stated that she was ready to begin the protocol. At the end of the session, speakers were paid for their participation, and were informed that their conversational speech during the set-up portion of the experiment had been recorded. Speakers were given a separate consent form to initial indicating that they approved of the use of this sample.

Motor Task

The motor task consisted of screwing a nut onto a bolt (1/2″ × 6″ full thread). Speakers were instructed to hold the screw in their left hand and then turn the nut with their right hand (the dominant hand for all speakers). Speakers briefly practiced screwing the nut and bolt in each hand while the investigator watched to be sure they understood the directions and could perform the task. Speakers wore a black cloak with their hands positioned on their lap to avoid visual distraction. A second investigator was positioned to watch the speaker's hands to ensure that they continued turning the nut. If a speaker stopped or slowed, they were verbally prompted to continue. No measures of the motor task were collected.

Acoustic Analysis

Acoustic analyses were used to describe any differences in suprasegmental production (i.e., intensity, rate, fundamental frequency variation) between the recording conditions (single- vs. dual-task). Acoustic measurements based on the sentence, monologue, and spontaneous speech tasks were completed using the Windows-based version of Cspeech software, TF32 (Milenkovic, 2002). Prior to analysis, the monologue and spontaneous tasks were divided into runs that were operationally defined as a stretch of speech bounded by silent periods of at least 200 ms based on a glottal waveform/spectrogram display (Tjaden & Wilding, 2004; Turner & Weismer, 1993). Acoustic criteria such as stop release bursts, frication, or voicing energy, were used to identify the onsets and offsets of runs (Kent & Read, 1992). Transcripts for each speaker were typed verbatim without punctuation, and the first author and a research assistant marked run boundaries on the transcripts. They did not agree on 3.4% of the boundaries. In these cases, they discussed the criteria used to identify the boundary and reached to a consensus prior to marking a final boundary.

Speech rate was measured using a combined waveform and wideband spectrographic display. Speech rate was computed as syllables per second (syl/s) for the sentence or run. Speech rates for each trial within a given speech task were averaged, yielding a mean rate for each speaker, speech task, and condition.

Sound pressure level (SPL) was measured for each sentence or run. The calibration tone was retrieved and a TF32 software routine was used to convert RMS voltage to dB SPL. SPL values for each trial within a given speech task were averaged yielding a mean SPL for each speaker, speech task, and condition.

An automatic pitch tracker in TF32 was used to compute fundamental frequency (F0) contours for each sentence or run. Each F0 contour was visually inspected and manually corrected to eliminate spurious values (too high or low). The typical F0 range (mean, minimum, and maximum) for each sentence or run was recorded. These values were used to describe the typical use of F0 in sentence production by the speakers for each condition.

Language Production

Previous work (Garrett, 1982; Levelt, 1989; Jou & Harris, 1992) has shown that divided attention tasks disrupt message construction and the flow of speech output. To evaluate whether the motor task used in the present study had an effect on the language produced by the speakers, a number of measures were made. Transcripts for the monologue and spontaneous speech tasks for each speaker were typed verbatim without punctuation. Two judges marked clause boundaries on the transcripts. Both judges had greater than 10 years experience in research in the area of language science and were blind to both the purpose of the study and the participant diagnosis. The criterion for marking a clause boundary was that it contained a finite verb. Incomplete grammatical utterances, such as restarts, were not counted as independent clauses, but were included in the following complete clause. After clausal boundaries were marked, the duration of pauses within and between clauses was recorded using a combined waveform/spectrogram display in TF32. Using the marked transcripts the following counts were made: within clause pauses (5 s or longer), between clause pauses (5 s or longer), number of self-corrections, number of false starts (repetition of syllables, words, phrases, or clauses), number of sentence fragments, use of indefinite pronouns (e.g., things, stuff), and violation of basic grammatical rules. These analyses are based on work by Jou and Harris (1992).

Listening Task

Speech samples were presented over a loudspeaker placed 1 meter in front of each listener and he/she was asked to write down what he/she heard each speaker say as accurately as possible. Each listener received written and oral directions for the task. Due to the likelihood of learning effects, each listener heard 71 single words, 30 HINT sentences, a monologue sample, and a spontaneous speech sample from two randomly selected speakers (1 PD, 1 CG). Only half of the HINT sentences from each speaker were played within a listening session to control listener familiarity with the sentences. For the monologue and spontaneous speech tasks, the samples were segmented by runs as described above, and sixty runs were presented to each listener for each monologue and spontaneous task. Runs were presented to the listeners in a random order to avoid any influence of context on intelligibility score. Speech samples presented to the listener in a single listening session were not necessarily produced by the same speaker; however, each listener heard all four speech tasks for an equal number of speakers in the CG and PD group. For example, listener 1 may have heard words produced by speakers PD1 and CG3, sentences from speakers PD2 and CG1, a monologue from speaker PD4 and CG3, and spontaneous speech from speaker PD2 and CG2. In total, each speech sample was heard by a total of 10 listeners. Eight second pauses were included between presentations to allow the listener to write down what he/she heard. Each listener participated in two separate listening sessions with each session lasting no more than 30 minutes.

Intelligibility Analysis

Intelligibility scores for each speaker were determined by counting the number of correctly identified words and dividing by the total number of words possible for that speech task. Scores were then averaged across the listeners. Synonyms or responses reflecting morphological variations, such as *cat* for *cats*, were considered incorrect. Misspellings (e.g., theif for thief) and homonyms (e.g., rode for rowed) were accepted as correct. Two judges (the first author and a research assistant) scored the number of correct words per sentence and these scores were compared. When scores were not in agreement (<3% of samples), the judges discussed the scores and came to a consensus before a final score was assigned.

Statistical Analysis

Five planned pairwise comparisons were completed per speaker group. The first three comparisons were of intelligibility scores for each of the three speech tasks in the single- vs. dual-task conditions. The final two comparisons were of speech intelligibility scores measure in the spontaneous speech condition versus the monologue task in both the single- and dual-task conditions. A bonferroni correction was used to control alpha (.05/10=.005). Acoustic and language analysis results are presented descriptively.

Reliability

For the acoustic analyses, reliability was determined by re-measuring 10% of the tokens for each speaker across speech task and condition. Pearson product-moment correlations and mean absolute measurement errors were used to index reliability. Intrajudge reliability for SPL yielded a mean error of 0.05 dB SPL (SD=.41 dB SPL) and a correlation of .99 for the two sets of measures. Intrajudge reliability for temporal acoustic measures yielded a mean measurement error of 14 ms (SD=36 ms) and a correlation of .99. Intrajudge reliability for F0 measurement had a mean error of 22 Hz (SD=32 Hz) and a correlation of .99. To obtain measures of interjudge reliability, measures from the first author and a research assistant were compared. Interjudge reliability for SPL yielded a correlation of .99 and a mean error of 0.08 dB SPL (SD=.54). The mean error for interjudge reliability on temporal measures was 19 ms (SD=33 ms) with a correlation of .99. Interjudge reliability for F0 variation had a mean error of 32 Hz (SD=46 Hz) and a correlation of .99. In sum, all measures of reliability indicated good agreement.

Measures of inter- and intra-listener reliability were determined using Kendall's coefficient of concordance. Intrajudge reliability was determined by randomly selecting 10% of the tokens for each speaker across speech task and condition and replaying them to each listener within a listening session. The value of the coefficient for intra-listener reliability was W=0.861, indicating a high agreement within listeners. Interjudge reliability was obtained using the randomly selected tokens from each speaker across the 10 listeners who heard that set of tokens. The value of the coefficient was W=0.922. Kruskall Wallis ANOVA by ranks showed no significant order effect on overall intelligibility for listeners (H=1.21, p=.746), who had heard a randomly selected set of speakers with PD and from the CG.

Results

Speech intelligibility scores

Mean intelligibility scores and standard deviations for the CG measured for the each of the speech tasks and conditions are shown in Table 1. Differences in percent intelligibility were not statistically significant for the any of the three speech tasks in the single- vs. dual-task conditions [single words (t (39) =−1.064, p= .291(one-tailed)); sentences (t (39) =−1.51, p= .319(one-tailed)); monologue (t (39) =−2.104, p= .139(one-tailed))]. Differences between scores for the spontaneous speech sample compared to scores on the monologue in the single- and dual-task conditions were also not statistically significant [t(39)=1.64, p=.054; t(39)=2.11, p=.063, respectively].

Table 1 also shows the mean intelligibility and standard deviations for each speech task and condition for the PD group. Differences between conditions were statistically significant for all three speech tasks [single words (t (39) =−23.14, p=.000(one-tailed)); sentence task (t (39) =−15.03, p=.000(one-tailed)), monologue (t (39) =−16.51, p=.000(one-tailed))]. Large standard deviations in both the single- and dual-task conditions were noted for the PD group. To explore individual differences, data shown for individual speakers by condition and speech task are shown in Figure 1. Percent intelligibility measured for each speaker in the spontaneous speech task is also shown in the figure. For speakers in the PD group, the difference in intelligibility scores between the spontaneous sample and the monologue task in the single task condition was statistically significant [t(39)=−21.40, p=.000]. On average, scores for the single-task condition were 12.6% higher. The difference between the spontaneous sample and the monologue task in the dual-task condition, however, was not statistically significant [t(39)=−1.96, p=.039]. The intelligibility scores measured in these two tasks were comparable.

Speech rate

Mean speech rate measured during the spontaneous task, and sentence and monologue tasks in the single- and dual-task conditions are shown in Figure 2 for the PD group. Speech rates were slowest for both speech tasks in the single-task condition (3.35 and 3.59 syl/s for the sentence and monologue tasks, respectively) compared to the dual-task condition (4.03 and 3.77 syl/s, respectively) and the spontaneous speech task (4.2 syl/s).

Fundamental frequency variation

Mean F0 variation for the PD group is shown in Figure 3 for the spontaneous speech task and sentence and monologue tasks in the single- and dual-task conditions. Mean F0 variation measured for the sentence and monologue tasks in the single-task condition were greater than the same tasks in the dual-task condition and the spontaneous task. F0 variation in the dual-task condition was only slightly greater than that measured in the spontaneous speech task (8.5 Hz. for the sentence task and 2.2 Hz. for the monologue task).

Sound Pressure Level

Mean SPL across PD speakers are shown in Figure 4. The mean dB SPL was greatest for the tasks in the single-task condition followed by tasks in the dual task-condition. Mean dB SPL was lowest for the spontaneous speech task.

Language production

Mean values (counts and standard deviations) for each of the language measures in the spontaneous task and monologue task in the two conditions (single-task & dual-task) are shown in Figure 5.

Discussion

A major finding of the present study was that intelligibility was reduced for single word, sentence, and monologue speech tasks in the dual-task condition compared to the single-task condition for speakers with dysarthria associated with PD. The differences between conditions were statistically significant for all three speech tasks. No differences in intelligibility were found for the CG across condition. These results are consistent with the original hypothesis. A second finding was that the intelligibility scores for the monologue task in the single-task condition and spontaneous task were significantly different for the PD group. Differences between the monologue task in dual-task condition and the spontaneous task, however, were not significantly different for the PD group. Intelligibility scores measured for these tasks were similar for all four speakers. No differences were seen for the CG on these tasks. These data provide preliminary support for the use of a dual-task paradigm as a means to obtain measures of intelligibility in a clinical or laboratory setting that are representative of functional communication abilities for speakers with dysarthria related to PD.

Data for speakers in the CG shows a negligible difference in intelligibility scores across condition (Table 1). This suggests that the demands of the secondary motor task used in the present study were not adequate to have an effect on speech intelligibility and thus speakers were able to perform sufficiently well on both tasks (although no measures of motor behavior were collected in the present study). This finding was not unexpected. Schiavetti, Whitehead, and Metz (2004) reported similar findings from a series of studies looking at the effect of increasing demands of a manual task on speech production in normal speakers. They reported that temporal disruptions in speech production were minimal for simple motor tasks and became larger as the manual task became longer or more complex. Their motor tasks increased from base signs with minimal movement of one-hand to elaborate signs involving two hands and rapid finger spelling. The motor task used in the present study, turning a nut on a bolt, could be considered less complex than even the base signs in their experiments, as it involved only small movement of one hand and does not carry meaning the way a sign does. The negligible differences across conditions found in the present study conflicts with findings by Dromey and Benson (2003) who reported significant differences in lip movement amplitude and peak velocity in a dual-task condition compared to a single-task condition for healthy speakers. There are two possible explanations for the discrepant findings. First, intelligibility is a global measure of speech production and involves both the speaker and the listeners. It is not sensitive to small changes in production as measures of movement of a single structure such as that examined by Dromey and Benson. Second, the motor task used by Dromey and Benson was visually guided (assembling washers, nuts, and bolts). There is evidence of relative advantage of tasks that involve visual stimuli over those that do not in the literature (Morris Iansek, Matyas, & Summers, 1996;Lindenberger, Marsiske, & Baltes, 2000;Li, Lindenberger, Fueund, & Baltes, 2001). Therefore, comparison of the effects of a motor distractor task in the two studies may not be appropriate. Further study of the effects of different types of motor tasks on speech production for healthy speakers is of interest to reconcile these findings.

All four speakers in the PD group had higher speech intelligibility scores in the single-task condition compared to scores measured in the dual-task condition. The differences were statistically significant for all three speech tasks. It was hypothesized that in a structured setting, such as a single-task condition, where speakers had explicit knowledge of the goal of the task, they would be able to focus their attention on speech production thus enhancing performance. Decrements in performance seen in the dual-task condition, therefore, could be due to competition for resources, increased attentional capacity being devoted to the motor task at the expense of the speech task, or a reflection of a reduced overall level of attentional capacity among others. Differences in intelligibility scores found in the present study support these hypotheses and are consistent with previous studies of gait and handwriting (Morris, Iansek, Matyas, & Summers, 1996; Oliveira et al., 1998). In these studies and the present study, the improvements in performance did not report a ‘normalization’ of performance but rather an improvement in performance in conditions when attention was focused on a specific task compared to conditions where attention was not controlled.

The higher intelligibility scores in the single-vs. dual-task conditions were supported by changes in the acoustic characteristics of the speech. For example, the speech rate measured in the single-task condition was slower than that measured in the dual-task condition. The slow speech rate was consistent with other studies reporting that speakers with PD voluntarily slow their speech rate for sentence-level and short reading passages in clinical settings (e.g., Hammen, Yorkston, & Beukelman, 1988; McRae, Tjaden, & Schoonings, 2002; Tjaden & Wilding, 2004; Turner & Weismer, 1993) and has been associated with increased conscious processing of the task of speech production (Feyereisen, 1997; Dagenais, Brown, & Moore, 2006). Greater F0 variation was also noted in the single-task condition compared to the dual-task condition (Fig. 3). Although F0 variability was restricted considerably compared to neurologically healthy individuals, where F0 typically ranges from 70-150 Hz during spontaneous speech production (Silverman, 1987; Kim, 1994), variability in the single-task condition was greater than the dual-task condition. Increased F0 variability likely translated into perception of increased prosodic stress in the single-task condition and may have affected overall speech intelligibility. The improvements in performance found for all three speech tasks in the single-task condition represent a decrease in Parkinsonian related deficits. The competition for resources created by the dual-task condition forced speakers to sacrifice performance on one task to adequately complete both tasks simultaneously. The findings support the hypothesis that allocation of attention does affect speech production performance in this population, and are consistent with both theories of attention presented in the introduction, resource allocation and time series.

The statistically significant difference between conditions for all three speech tasks was somewhat surprising. It should be noted, however, that the relation of the scores to each other within condition was the same. Previous research has suggested intelligibility in single-word tasks may be preserved, but may be degraded in sentence and conversational monologue tasks when recording conditions were changed (Frearson, 1985; Kempler & Van Lancker, 2002; Tjaden & Wilding, 2005; Yorkston & Beukelman, 1978). In these studies changes were related to location and communication partner rather than inclusion of a secondary task, therefore, findings may not be directly comparable. In the motor control literature it has been suggested that if one of the tasks performed in a dual-task condition is novel, it will have a more negative effect on the other task if that task is a fairly automatic behavior that is carried out without much conscious attention, as compared to a case where both tasks are well practiced (Morris, Iansek, Matyas, & Summers, 1996). In the present study, the nut-bolt task which was performed without visual guidance may have been sufficiently novel that speakers sacrificed performance on the speech production task in order to complete both tasks simultaneously. If the secondary task were one that is more routinely performed while speaking, such as walking or preparing a meal, it is not known whether differences would be found for all three speech tasks.

The premise for eliciting the monologue task in the single-and dual-task conditions and the spontaneous speech sample was similar in the present study, the only difference between the tasks was the speakers' knowledge of expectations for that task, and therefore it was believed that performance on the monologue tasks would be most comparable to typical speech production. Results showed statistically significant differences in speech intelligibility scores measured for the monologue task in the single-task condition and the spontaneous task. This finding is consistent with previous reports of performance effects for speakers with PD in clinical and laboratory settings (Sarno, 1968; Weismer, 1984; Keintz et al., 2007). The difference in scores varied for individual speakers with differences ranging between 9 and 16% (Fig. 1). The difference between scores for the monologue task in the dual-task condition and the spontaneous task, however, was not statistically significant and ranged between 1 and 4% for individual speakers (Fig. 1). This finding suggests that the monologue task in the dual-task condition and the spontaneous speech task were characterized by more prominent Parkinsonian deficits compared to the monologue task in the single-task condition or the other speech tasks examined. This is supported by the acoustic analyses, where speech rate, F0 range, and intensity were most similar for the monologue (dual-task condition) and spontaneous tasks compared to the other tasks and condition (Figs. 3-5). Remarkably, inclusion of a dual-task did not have a significant effect on language production based on the measures examined (Fig. 5). This finding is in contrast to a study by Jou and Harris (1992) where they reported significant differences for a monologue task in single- and dual-task conditions on language production measures. In the Jou and Harris (1992) study, however, a mental arithmetic task was used as the secondary task, which reportedly carried a substantial cognitive load and perhaps suppressed the message construction process at the conceptual level (see also Garrett, 1982; Levelt, 1989). It is possible that the motor task used in the present study did not create a competition for resources (i.e., there was no single modality interference), as described by Jou and Harris, and therefore should not have been expected to affect the linguistic characteristics of the speech samples. This issue warrants further study. Similarities in performance for the monologue task in the dual-task condition and spontaneous task provide that a dual-task condition may be a means to obtain measures of intelligibility in a clinical or laboratory setting that is representative of functional communication abilities in this population. In terms of practical application, use of a motor task as the secondary task appears appropriate as the negative affects appeared to be limited to the motor-based task of speech production while language, not a motor based activity, was not affected.

No measure of manual performance was made in the present study, therefore, it is not possible to comment on any decrements in motor performance that speech may have caused. In addition, speculation about the relation between performance and attention in different conditions cannot be made. Future studies, designed to examine how performance on a given task changes as a function of level in a secondary task and are counterbalanced by observations of changes in performance of a secondary task as a function of variation in levels of the primary task, are needed to address these issues. Despite limited theoretical implications, the negative effect of performing a motor task simultaneously with speech production was noteworthy and has potential clinical utility.

Summary and Conclusions

Results of the study provide preliminary support for use of a dual-task paradigm as a means to collect speech samples in a clinic or laboratory setting that were representative of a speaker's spontaneous speech in terms of intelligibility, thus eliminating discrepancies between clinical and ecological manifestations of the dysarthria associated with PD. The small sample size in the present study limits generalization, thus additional studies involving larger sample sizes, multiple etiologies, speaker sex, and different types of motor tasks are warranted to replicate the findings of the present study.

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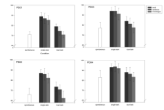

Figure 1.
Means and standard deviations for intelligibility scores by speech task and condition for individual speakers in the PD group.

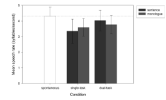

Figure 2.
Mean speech rate (and standard deviation) for the PD group in the spontaneous task (white bar) and the sentence and monologue tasks in the single- and dual-task conditions.

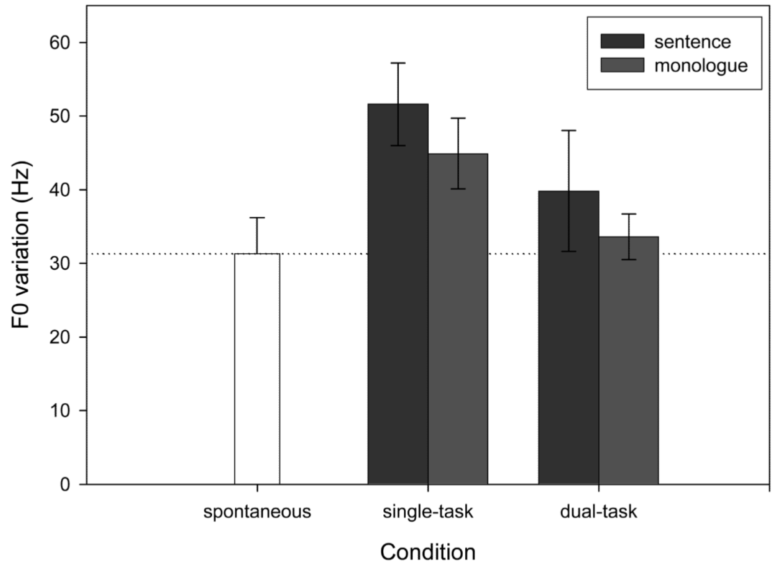

Figure 3.
Mean fundamental frequency variation (and standard deviation) for the PD group in the spontaneous task (white bar) and the sentence and monologue tasks in the single- and dual-task conditions.

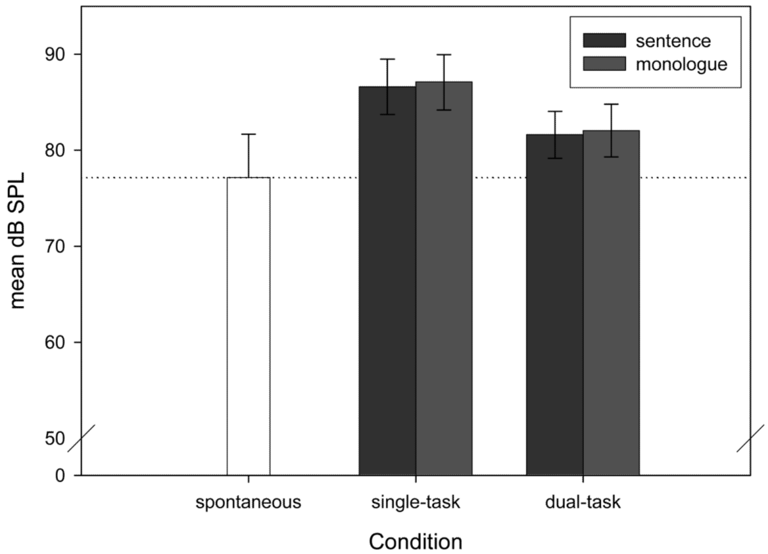

Figure 4.
Mean intensity (and standard deviation) for the PD group in the spontaneous task (white bar) and the sentence and monologue tasks in the single- and dual-task conditions.

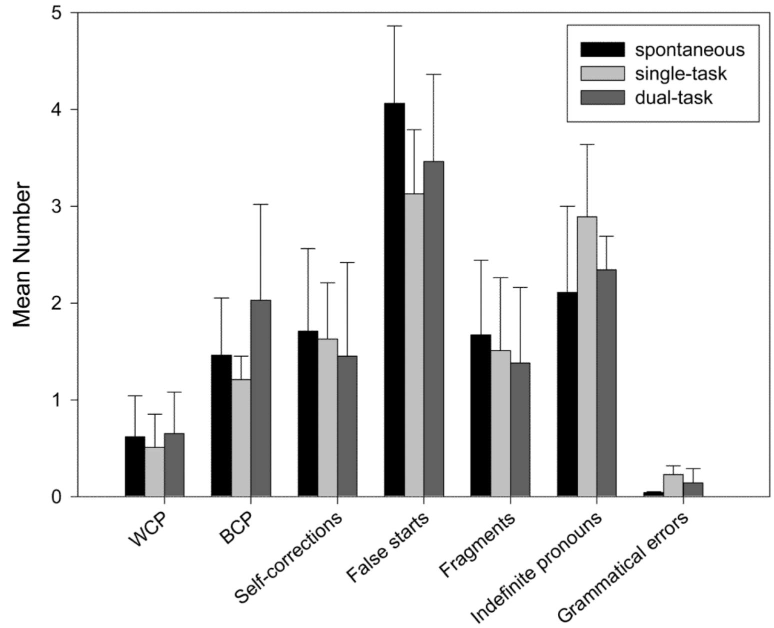

Figure 5.

Counts for the various language measures across speech tasks and conditions. Categories listed on the x-axis include: within clause pauses (WCP), between clause pauses (BCP), self-corrections, false starts, sentence fragments, use of indefinite pronouns, and grammatical errors.

Table 1

Mean intelligibility scores and standard deviations (in parentheses) by condition and speech task for the two speaker groups.

Speaker Group	Speech Task	Spontaneous	Single Task	Dual Task
CG	Single words	__	99.09 (0.4)	98.7 (0.7)
CG	Sentences	__	98.09 (1.0)	98.8 (1.1)
CG	Monologue	98.4 (2.4)	97.45 (0.8)	97.6 (0.9)
PD	Single words	__	90.75 (5.9)	81.15 (11.3)
PD	Sentences	__	90.2 (4.2)	78.28 (13.8)
PD	Monologue	74.25 (14.3)	87.5 (7.4)	73.52 (13.1)