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Dramatic effects of speech task on motor and linguistic planning in severely dysfluent parkinsonian speech

DIANA VAN LANCKER SIDTIS[1,2], KRISTA CAMERON[2], & JOHN J. SIDTIS[2,3]

[1]*Department of Communicative Sciences and Disorders, New York University, New York, NY, USA,* [2]*Brain and Behavior Laboratory, Geriatrics Division, Nathan Kline Institute for Psychiatric Research, Orangeburg, NY, USA, and* [3]*Department of Psychiatry, New York University School of Medicine, New York, NY, USA*

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Abstract
In motor speech disorders, dysarthric features impacting intelligibility, articulation, fluency and voice emerge more saliently in conversation than in repetition, reading or singing. A role of the basal ganglia in these task discrepancies has been identified. Further, more recent studies of naturalistic speech in basal ganglia dysfunction have revealed that formulaic language is more impaired than novel language. This descriptive study extends these observations to a case of severely dysfluent dysarthria due to a parkinsonian syndrome. Dysfluencies were quantified and compared for conversation, two forms of repetition, reading, recited speech and singing. Other measures examined phonetic inventories, word forms and formulaic language. Phonetic, syllabic and lexical dysfluencies were more abundant in conversation than in other task conditions. Formulaic expressions in conversation were reduced compared to normal speakers. A proposed explanation supports the notion that the basal ganglia contribute to formulation of internal models for execution of speech.

Keywords: *task effects*, *Parkinson's disease*, *dysfluency*, *motor speech planning*, *basal ganglia*

Background

Motor speech naturally occurs as various vocal tasks, such as spontaneous (or conversational) speech, repetition and reading. It was previously assumed that articulatory and voice characteristics were stable across tasks in normal speech, and that dysarthria occurred consistently regardless of task demands (Yorkston, Beukelman, & Bell, 1988). Further, uniformity across speech tasks has been described for neurogenic stuttering (Canter, 1971; Helm-Estabrooks, 1999). However, recent studies of motor speech disorders have compared articulatory and voice characteristics in different task configurations and found important differences. Speech measures differ for spontaneous speaking, repetition, reading aloud (Brown & Docherty, 1995; Canter & Van Lancker, 1985; Kempler & Van Lancker, 2002; Laan, 1997; Sidtis, Rogers, Godier, Tagliati, & Sidtis, 2010), vowel prolongation (Kent & Kent, 2002), speaking at different rates (Caligiuri, 1989; Dressler, 1975; Miller & Volaitis, 1989) and speaking while cued by a visual stimulus (Hustad, Dardis, &

Correspondence: Diana Van Lancker Sidtis, Department of Communicative Sciences and Disorders, New York University, 665 Broadway, 9th Floor, New York, NY 10012, USA. Tel: +1 917-224-5483. Fax: +1 845 398 5575. E-mail: diana.sidtis@nyu.edu

McCourt, 2007). Recent studies examining the effects of task on speech focused on intelligibility by listeners (Kempler & Van Lancker, 2002; Sidtis, Cameron, Bonura, & Sidtis, 2012) and on acoustic measures of a group of mildly dysarthric speakers (Sidtis et al., 2010). Spontaneous speech was as much as 30% less intelligible than matched repeated phrases, and acoustic measures revealed that repetition, voice and fluency were improved in repeated as compared with spontaneous exemplars. Thus, the previous view that voice, articulation, fluency and intelligibility are consistent across tasks is no longer viable, and task has been shown to affect measurable aspects of articulated speech and voice.

Singing is a vocal mode that is known to yield neurologically related performance differences. Singing is preserved in severe aphasia following left-hemisphere damage (Hughlings Jackson, 1874 [1932]) or removal (Burklund & Smith, 1977). Discrepancies in performance are seen in stuttering (Ludlow & Loucks, 2003), where dysfluencies prevalent in a speaking mode do not occur while singing (Glover, Kalinowski, Rastatter, & Stuart, 1996; Packman, Onslow, & Menzies, 2000). In a controlled study of parkinsonian dysarthria, intelligibility by listeners was significantly higher for sung than spontaneously spoken material (Kempler & Van Lancker, 2002). While clinical and experimental observations indicate that singing differs from speech in neural control, the contingencies surrounding this important contrast and the reasons for it are not clear. One of our interests was to further compare performance during singing with performance on verbal modes of vocalization in severe dysarthria.

There is a venerable history of studies in formulaic language supporting the proposal that overlearned, routinized expressions ("Thank you", "hello", "You've got to be kidding") are stored and processed differently from novel, propositional language (Hughlings Jackson, 1874 [1932]; Sinclair, 1987, 1991; Van Lancker, 1994; Van Lancker Sidtis, 2010; Wray & Perkins, 2000). These utterances include conversational speech formulas, idioms, swearing and a large array of other conventionalized expressions (Van Lancker, 1998) and constitute approximately 25% of talk (Van Lancker & Rallon, 2004). More recent investigations suggest that production of formulaic expressions and recited speech relies in large part on intact basal ganglia (Van Lancker & Cummings, 1999; Van Lancker Sidtis, in press). Subcortical dysfunction has been associated with deficiencies (Rogers, Sidtis, & Sidtis, 2010; Sidtis, Canterucci, & Katsnelson, 2009; Speedie, Wertman, T'air, & Heilman, 1993), while persons with intact basal ganglia, despite other neurological damage, show normal or increased levels (Bridges & Van Lancker Sidtis, 2012; Van Lancker Sidtis, 2012, in press).

In our studies of speech in Parkinson's disease (PD), we encountered an individual with severe dysfluency in spontaneous speech, but whose motor speech disorder was dramatically reduced when other speech tasks were elicited. We pursued controlled, quantitative analyses of these discrepancies, utilizing acoustically derived measures of rate and fluency. In addition, frequency analyses of phonetic elements most affected in the separate tasks were prepared. These measures were applied across five speech tasks and singing. We examined the participant's conversational speech focusing on lexical use and presence of formulaic language, drawing comparisons with speech from other cases of neurogenic stuttering and from healthy speakers (HS). The goal was to identify speech characteristics, particularly those that may reflect motor speech or linguistic planning, that differ with speech tasks (spontaneous, repetition in two versions, reading, recited speech), modes (formulaic versus novel) and singing, and to consider these results in the context of models of brain function underlying speech production.

Types of dysfluencies were characterized and compared in five selected speech tasks and singing. Phonetic prolongations and (non-word) syllable repetitions are assumed to arise from motor speech planning and execution, while repeated mono- and multisyllabic words are attributed to linguistic planning processes related to word retrieval. One of our interests was whether speech measures reflecting these two kinds of planning differed with speech tasks. To address a point in the neurogenic stuttering literature (Canter, 1971; Helm-Estabrooks, 1999), incidences of dysfluencies on content and function words were compared. Another question involved incidence of formulaic expressions in the spontaneous speech sample, as deficient formulaic language has been associated with basal ganglia dysfunction.

It has been proposed that the burden of internal planning differs with speech task (Kempler & Van Lancker, 2002). Conversational speech requires newly generated internal models of motor performance, while recited speech engages memorized internal models. In contrast, reading and repetition use externally provided models. Singing is a special case that has been shown to operate differently than speech in various neurological disorders. Quantification of identifiable types of dysfluencies (prolongations, syllable repetitions, monosyllabic and polysyllabic word repetitions) and status of lexical and formulaic expressions may provide more information on planning in vocal production.

Method

Subject

The participant, a person with a parkinsonian syndrome (PWPS), is a 64 year old, left-handed Caucasian male with 2 years of college education. He is a native speaker of American English, as were both of his parents. He was born and raised in New York City. The participant is an experienced musician and took part for many years as a tenor in church choirs. He received the diagnosis of atypical parkinsonian syndrome 5 years before testing in this study. His early symptoms were impaired smell and taste, fatigue, sleep disturbance, slurring of words, hypophonia, bradykinesia, shuffling gait with start hesitation, freezing and falling, balance problems, internal tremor and micrographia. This presentation is consistent with basal ganglia dysfunction (Duffy, 1995). Three years later, his speech started to become progressively dysfluent. PWPS had no previous history of speech or language problems. Now on disability, PWPS worked as a private contractor in the arts and in a service industry. No contributing family history was noted.

On examination by a speech pathologist (DS, first author), PWPS's spontaneous speech was characterized by alternating fluent and severely dysfluent phases including prolongations (or blocks) and repetitions of phonetic elements, syllables and words. The diadochokinetic testing indicated that speech rate, coordination and precision in speech task were impaired. Rate in this performance was abnormally rapid with a mean of 20 repetitions of /pa/, 24 repetitions of /ta/ and 30 repetitions of /ka/ per 2 s. Speech rate was increased with short rushes. Breathing was insufficient for functional breath groups of speech: the subject's breath ran out, for example, after 4 s in the diadochokinetic task and before spontaneous utterances were completed. In the vowel prolongation task, maximum phonation times for /a/, /i/ and /u/ were approximately 9 s, which is below normal limits. Pitch, voice quality and loudness on clinical examination were unremarkable.

The most salient feature in the speech of PWPS was stuttering. Dysfluency is not an unusual occurrence in parkinsonian dysarthria (Benke, Hohenstein, Poewe, & Butterworth, 2000; Canter, 1971). Of 200 words in the initial conversational sample, 19 (10%) were dysfluent. The dysfluent phases were marked by lengthy blocks and prolongations of phones and by multiple repetitions of consonants, vowels, syllables and words ranging from 1 to 18 s in duration. Three main types of dysfluencies appeared: initial sounds (e.g. "t…t…t ..tenor"), syllable repetitions (e.g. "wa..wa.. wa…wa…worked for advertising") and whole word repetitions (e.g. "I sang for the glee glee glee glee glee club"). As observed by Koller (1983) for parkinsonian stuttering, he did not show anxiety or secondary stuttering characteristics. The participant was aware of his speech disorder, reporting his most difficult phonemes to be /l/ and /m/.

There was a dramatic reduction of stuttering when structured speech tasks and singing were introduced. When asked to sing a familiar song, although a former singer in church choirs, PWPS at first declined, stating that he was no longer able to sing. When encouraged to try, he became emotional on discovering that he was able to sing competently, with well articulated, fluent lyrics, strong expression and good pitch control.

Procedure

Two separate sets of speech samples were obtained at clinical speech examinations 10 days apart and recorded on digital audio (Marantz digital recorder, PMD660) with an Audio-Technica cardioid microphone, (AT3035) and digital video (Sony DCR-SR88) recording devices. Seven vocal samples were obtained at two separate times: *conversation, conversation–repetition* (see explanation below), *reading, recited speech, sentence repetition and singing* (Table I). For the *conversation* samples, the subject described family, personal history and musical interests. From both sessions, 6 min of speech were transcribed and analyzed for a total of 587 words (see Appendix 1). (To establish word counts of transcribed speech samples, all complete words, but not phonetic prolongations or repeated syllables, were included.) Two approaches to *repetition* measures were taken: *conversation–repetition* and *sentence repetition* (see below). For the *conversation–repetition task*, 90 phrases, totaling 531 words, were excerpted from the spontaneous speech samples. The list of phrases, two to eight words in length, drawn equally from fluent and dysfluent portions of the speech, were presented in a repetition format. This procedure allowed for direct comparison of identical phrase-types produced in the conversation and repeated speech tasks (see Kempler & Van Lancker, 2002). From the corpus of 90 repeated phrases, 45 phrases (234 words) were randomly chosen for analysis. The *reading task* utilized the Rainbow Passage. For the *recitation task*, well-known nursery rhymes (e.g. Humpty Dumpty, Jack and Jill), prayers (e.g. Lord's Prayer) and the Pledge of Allegiance were elicited (198 words). In the *sentence repetition* task, the subject repeated four statements and four questions, six to seven words in length, spoken by the examiner. The examination included *singing* of songs, endorsed as familiar, such as Happy Birthday, Jingle Bells and Deck the Halls (154 words) (see Table 1 and Appendix 1).

Measures

A detailed, orthographic transcription of each speech sample was performed independently by two persons trained in speech pathology, and discrepancies were resolved by discussion. The difficulties in identifying dysfluencies in connected speech are well known (Perkins, 1990). To achieve precise, meaningful and consistent measurements, various approaches were taken. Recorded samples representing conversation, conversation–repetition, reading, recitation, sentence repetition and singing were visually displayed for accurate measures (PRAAT, Boersma & Weenink, 2005). Dysfluent speech in the form of nonsyllabic dysfluencies (thththth), syllabic dysfluencies (babababa) and repeated lexical elements (the the the) were quantified. Because word counts differ for the

Table I. List of tasks and word counts for texts utilized in each task.

Speech task	Words/duration
Conversation	587
Conversation–repetition	234
Recited speech	332
Reading	198
Sentence repetition	219
Singing	154

various tasks, measures are presented as proportional to the total words for each speech task. In one measurement approach, "target words", those inferred to form the intended communication, were tabulated and compared to the actual production. Lengthy silences (up to 12 s) in the form of blocks also occurred. Therefore, a temporal measurement was used to compare estimated as compared with actual time taken to achieve an utterance.

Ratio of actual to target syllables

Actual productions were compared to estimated target productions for words and syllables, deriving a ratio of target to actual speech production. For example, in conversation, PWPS said 'use it use it because it thththththth un unununununununun unlike the sssolid state'. Target word production was estimated to be "use it because unlike the solid state" at 7 words, and actual word production is measured at 11 words. For the syllable count, the utterance is measured as comprising (an ideal) 10 target syllables but 23 actual syllables (nonsyllabic phonetic prolongations were not counted as syllables (Ladefoged, 2006). In tabulating lexical repetitions, separate counts were made for monosyllabic and polysyllable words, as polysyllabic words may more reliably reflect word retrieval processes.

Temporal measure: ratio of dysfluent to functional speech

The previous measure, comparing actual words or syllables to target words or syllables, did not capture the lengthy phonetic prolongations and blocks in the speech. Therefore, a second measure was used to represent time taken for nonsyllabic repetitions (thththththth) and prolongations (sssolid) (as well as repeated syllables and words), proportions of dysfluent to inferred functional speech in each sample were determined and expressed in temporal terms. That is, the time in an utterance was spent in dysfluent compared to linguistically competent (using the measure "target words") production was calculated. This measure allowed for all dysfluently repeated words, syllables and phonetic elements, including blocks, to be accounted for. In addition, speech rate, expressed as words per minute (WPM) (utilizing the corpus word count methodology described above), was established for all speech tasks.

Phonetic inventories

Frequency hierarchies of dysfluent phonetic elements for each speech task were established (Zeplin & Kent, 1996). The frequency chart of affected phonetic elements was compared with a chart representing target phonemes in the speech samples for each task, and with charts for normal speakers (Fry, 1947; Mines, Hanson, & Shoup, 1978).

Word types

Content words (nouns, verbs, adjectives and adverbs) and function words (articles, prepositions, relative and coordinating conjunctions and auxiliary verbs) were identified in spontaneous speech. The proportion in each grammatical grouping that carried dysfluencies was calculated and compared.

Formulaic language

Using previously published methods (Van Lancker & Rallon, 2004), proportions of formulaic language were calculated in the conversational speech. These were compared with values obtained from HS (Bridges & Van Lancker Sidtis, 2012; Sidtis et al., 2009; Van Lancker Sidtis & Postman, 2006). Formulaic language has been suggested as a significant component of the basal ganglia's role in producing normal spoken language.

Results

Fluency

The clinical impression that conversation was more dysfluent than the other speech tasks was supported by the measurements. The ratios of actual to target words and syllables in each task, shown in Figure 1, show substantially more phonetic prolongations and repeated syllables and words in spontaneous speech than in the other task conditions. Conversation–repetition (PWPS's repetition of phrases excerpted from his previous conversation), recited speech and reading show only modest increases over the target numbers. In sentence repetition, a few words were missed, probably as a failure of memory, and, as an anomaly in the overall performance, prolongations appeared twice in the sentence repetition task on words beginning with /s/. Singing shows the fullest success in producing the target to actual ratio, depicted as a horizontal line of 1.0 on Figure 1.

Figure 2 displays percentage of time taken for fluent material for each of the five speech tasks and singing in proportion to phonetic prolongations and syllabic and lexical repetitions. Time utilized for fluent speech (as a proportion of total time in the utterance) was the shortest, 66.9%, for the conversation task compared to 78.2 for conversation–repetition, 73.2 for recited speech, 93.6 for reading, 80.5 for sentence repetition and 97.0 for singing.

The effect of task on speech variables is reflected in the rate measure. Spontaneous speech in conversation was spoken at 100.8 WPM, slower than normal rates (reflecting longer periods of dysfluency), compared to reading at 297 WPM, faster than normal rates. (In normative studies, mean speaking rates for 180 subjects were 172.6 WPM for conversation, 188.4 WPM for reading of the Rainbow Passage (Kent, 1994).)

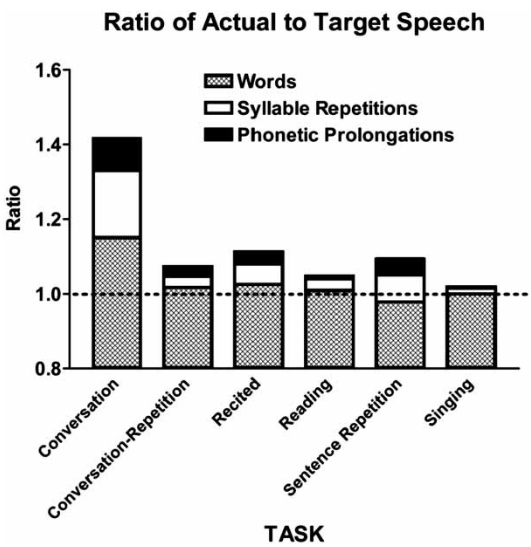

Figure 1. Ratios of actual to target speech, including prolongations, syllabic and lexical (word) repetitions as a function of task. The ratio represents the number of actual speech items divided by the number of target speech elements. The dotted line represents an equal number of actual and target items. Values greater than one indicate dysfluency.

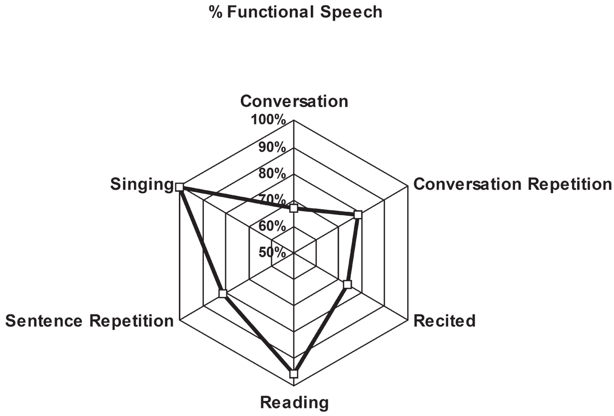

Figure 2. Percentage of time spent using fluent speech in each speech task corpus. Each task is represented at a corner point in the hexagon. The origin represents 50% of functional speech and the distal extreme represents 100% of functional speech.

Phonetic inventories

To determine an inventory of phonetic elements affected in the PWPS, a frequency count of target phonetic elements (those expected from normal, fluent speech) was established for each task. Word counts for each text are included. The frequency table for target phonemes for each task was modeled after published phoneme frequency charts for English (Fletcher, 1953; Fry, 1947; Kent, 1994), with alveolar consonants heading the list in frequency (with the exception that /n/ is not frequent in our conversation sample). In Table II, presenting a frequency chart of actual dysfluencies notated for each task, the most afflicted phoneme across all tasks, except singing, is the fricative. Clusters were minimally affected. Again, a higher incidence of disordered phonemes appears in the spontaneous sample. This fact is schematized in Figure 3, showing relative incidence of eight phonetic elements in the four prominent tasks, conversation, conversation–repetition, reading and recited speech.

Lexical analyses: polysyllabic words and grammatical word-types

In comparing incidence of lexical repetitions, only spontaneous and recited speech contained polysyllabic lexical dysfluencies (Table III). Combining the two conversational samples, stuttering incidence on content versus function words was found to be very similar, with 18.7% of all content words and 16.7 of all function words observed to be dysfluently produced.

Formulaic language

The proportion of words in formulaic expressions was 16.5%, which is significantly lower than seen in normal-control subjects (25%), and corresponds to values obtained for other persons with subcortical damage (Rogers, Sidtis, & Sidtis, 2010; Sidtis, Canterucci, & Katsnelson, 2009; Van Lancker Sidtis, 2012) (see Figure 4). The proportion is also significantly lower than that found for persons with Alzheimer's disease (AD), who have a cortical disease that spares the basal ganglia until the latest stage.

Discussion

This case study of adult-acquired neurogenic stuttering following a diagnosis of atypical parkinsonian syndrome allowed a detailed examination of the effects of vocal task on specific speech characteristics

Table II. Phoneme frequency counts and percentages for dysfluent phonemes in texts.

Percentage of dysfluency					
Conversation	Conversation repetition	Recited speech	Reading	Sentence repetition	Singing
Word count: 587	Word count: 234	Word count: 332	Word count: 198	Word count: 219	Word count: 154
/s/-13/50 = 26%	/ʃ/-1/7 = 14%	/ʃ/-1/7 = 14%	/ θ /-1/1 = 100%	/z/-9/48 = 19%	/r/-1/9 = 11%
/ð/-9/41 = 22%	/d/-2/24 = 8%	/p/-1/8 = 13%	/s/-1/3 = 33%	/g/-1/8 = 13%	/w/-1/20 = 5%
/f/-6/33 = 18%	/s/-1/15 = 6%	/d/-2/17 = 12%	/d/-1/12 = 8%	/ θ /-1/8 = 13%	
/ʃ/-1/6 = 17%	/n/-1/17 = 6%	/g/-1/9 = 11%		/d/-1/32 = 3%	
/p/-2/12 = 17%	/k/-1/19 = 5%	/f/-2/18 = 11%			
/ θ / -1/8 = 13%		/w/-3/38 = 8%			
/b/-3/23 = 13%		/h/-1/16 = 6%			
/t/-6/73 = 8%		/s/-1/28 = 4%			
/w/-3/38 = 8%					
/r/-2/31 = 6%					
/l/-2/35 = 6%					
/h/-1/21 = 5%					
/g/-1/22 = 5%					
/k/-2/46 = 4%					
/z/-1/25 = 4%					
/n/-1/40 = 3%					
TC/TD	TC/TD	TC/TD	TC/TD	TC/TD	TC/TD
54/659	7/280	12/428	3/133	12/426	2/240
8.19%	2.50%	2.80%	2.26%	2.82%	0.80%
Clusters:	Clusters:	Clusters:	Clusters:	Clusters:	Clusters:
/tr/-1/1 = 100%					
/pr/-1/8 = 13%					
/st/-2/22 = 9%					

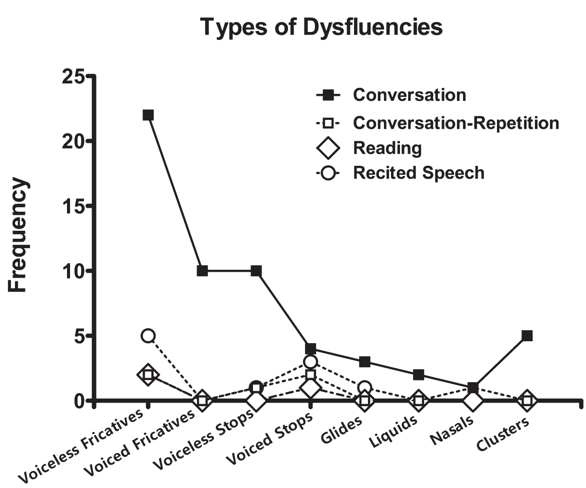

Figure 3. Type and frequency of phonetic dysfluencies for conversation, conversation–repetition, reading and recited speech. Moving from left to right on the x-axis the points represent voiceless fricatives, voiced fricatives, voiceless stops, voiced stops, glides, liquids, nasals and clusters.

Table III. Incidence of polysyllabic lexical dysfluencies and pause fillers by speech task.

	No. of dysfluent polysyllabic words	Percentage
Conversation	18	3.00%
Conversation–repetition	1	0.40%
Recited speech	9	2.70%
Reading	0	0.00%
Sentence repetition	0	0.00%
Singing	0	0.00%

possibly related to motor and linguistic planning. Damage to the basal ganglia (Lebrun, Leleux, & Retif, 1987) and disruption of functional connections with other brain areas have been associated with neurogenic stuttering (De Nil, Jokel, & Rochon, 2007). This subject's symptoms were consistent with basal ganglia damage. Our goal was to determine the characteristics of this motor speech disorder, with a special perspective on speech tasks and modes of linguistic competence.

A dramatic effect of speech task on measures of fluency, rate and phonetic inventory was found. On all fluency measures, spontaneous speech was more impaired than conversation–repetition, reading, sentence repetition or singing. Suggestions of disability also appeared for recited speech. The finding that conversation is more dysfluent than reading or repetition is not concordant with the claim that neurogenic stuttering is consistently uniform across various types of speech tasks (Helm-Estabrooks, 1999; Lundgren, Helm-Estabrooks, & Klein, 2010); and they directly contradict an early suggestion by Canter (1971) that in acquired stuttering, self-formulated speech is more fluent than repeated or choral speech. Our findings agree with a recent survey of neurogenic stuttering characteristics, in which 29% of patients with acquired neurogenic stuttering in neurological disease (stroke, trauma, neurodegenerative and other) stuttered “only during spontaneous speech and not during other speech tasks such as reading, singing and automatic speech” (Theys, van Wieringen, & De Nil, 2008, p. 13). In addition, our measures of similar proportions of dysfluencies on content and function words are in agreement with the previous literature (Helm-Estabrooks, 1999; Lundgren, Helm-Estabrooks, & Klein, 2010).

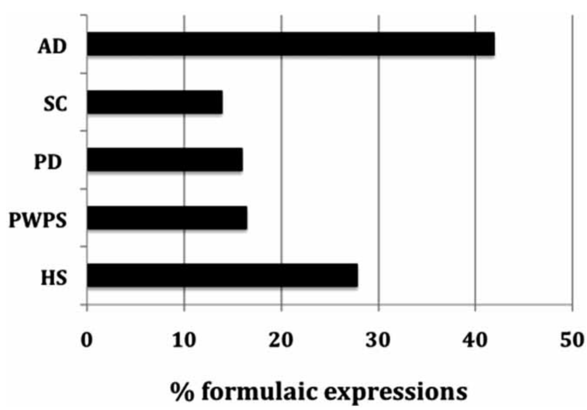

Figure 4. Proportion of formulaic expressions compared to other persons with and without subcortical disease and healthy speakers.
Notes: AD, Alzheimer's disease; SC, subcortical damage from stroke; PD, Parkinson's disease; PWPS, person with parkinsonian syndrome; HS, healthy speakers.

The increased dysfluency in conversation compared to other tasks is in agreement with comparative measures of speech rate in this subject, in which rates differed by task. Spontaneous speech yielded the lowest WPM value, likely due to the high number of phonetic dysfluencies; rate values during reading, the least dysfluent task, were the highest, approaching higher than normal values.

The results for fluency are consistent with previous studies (Canter & Van Lancker, 1985) showing differences between spontaneous and repeated speech, and between spontaneous speech and read, repeated and sung expressions (Kempler & Van Lancker, 2002). In the latter study, dysfluencies were significantly negatively correlated with intelligibility. In a group of mildly dysarthric persons with PD who had undergone deep brain stimulation (DBS), dysfluencies were greater in spontaneous production and DBS ON (Sidtis et al., 2010), when compared to two repetition tasks under the same conditions.

Types of dysfluency, phonetic disruptions and abnormal repetition of linguistic units (words) were also compared across tasks. More lexical repetitions occurred in spontaneous and recited speech than in the other conditions. Furthermore, abnormally repeated polysyllabic words occurred primarily in the spontaneous and the recited conditions (Table IV). These facts lead to the proposal that spontaneous and recited speech place greater demands on linguistic planning, initiation and monitoring of the vocal gesture than the other tasks, generating more errors in lexical retrieval. These tasks both require internal models for execution of the utterances. For conversation, the internal model is newly generated, while for recited speech the internal template is established from previous experience and procedural memory.

Phonetic elements most affected in spontaneous speech were voiceless and voiced fricatives and voiceless stops; these and all other phonetic elements were less disturbed in the other speech tasks. The severity metric for phoneme dysfluency did not match the subject's self report (identifying /m/ and /l/ as most problematic), nor did it agree with Canter's (1971) suggestion that /r/, /l/ and /h/ are dysfluency foci in neurogenetic stuttering. Others have noted that the relative rankings of deviant perceptual characteristics differed by task for individuals with dysarthria (Zeplin & Kent, 1996).

Consistent with previous measures of the effects of brain damage on incidence of formulaic language, the subject's proportion of formulaic expressions was lower than normal, and matched values obtained for other persons with subcortical dysfunction from stroke and PD (Van Lancker Sidtis, Pachana, Cummings, & Sidtis, 2006). A striking contrast is seen in the high incidence of formulaic expressions in persons with AD, who have intact basal ganglia (Rogers et al., 2010). The "dual process" model of language production posits a significant role of the basal ganglia for formulaic expressions, which make up about 25% of natural talk, while novel, newly created sentences are modulated primarily by the left hemisphere, where grammar and semantics are represented. There is considerable evidence for this view (Speedie et al., 1993; Van Lancker, McIntosh, & Grafton, 2003; Van Lancker Sidtis, 2004; Sidtis, Canterucci, & Katsnelson, 2009). Formulaic expressions are often retained following left hemisphere damage, while production and comprehension of grammatical, novel sentences are impaired (Van Lancker, 1994). These and related observations provide the foundation of empirical evidence for the dual process model of language processing. As the clinical presentation and neurological examination point to subcortical damage in this PWPS, these results are consistent with the dual process model (Van Lancker Sidtis, 2010). They also suggest that the simple dichotomy between motor and linguistic planning in the basal ganglia requires revision. While some might characterize formulaic utterances as "overlearned motor programs", this aspect of normal speaking clearly has linguistic and paralinguistic roles.

Explanations for waxing and waning of a motor speech disorder as an effect of task demands take various forms. For speaking, a fundamental reason for the discrepancy based on speech task may

Table IV. Phoneme frequency counts for all speech production tasks in target words.

	Total phoneme count				
Conversation	Conversation repetition	Recited speech	Reading	Sentence repetition	Singing
Word count: 587	Word count: 234	Word count: 332	Word count: 198	Word count: 219	Word count: 154
/t/-73	/t/-29	/t/-45	/t/-14	/z/-48	/l/-40
/d/-53	/d/-24	/n/- 42	/r/-12	/k/-40	/n/- 27
/s/-50	/k/-19	/w/-38	/d/-12	/d/-32	/t/-26
/k/-46	/v/-19	/r/-32	/ð/-11	/t/-26	/w/-20
/ð/-41	/f/-18	/m/-31	/n/- 10	/p/-24	/b/-19
/n/- 40	/w/-18	/l/-31	/l/-9	/m/-24	/h/-19
/w/-38	/n/- 17	/s/-26	/v/-8	/n/- 24	/p/-17
/l/-35	/s/-15	/z/-23	/z/-8	/v/-24	/dʒ/-15
/v/-33	/m/-15	/f/-18	/p/-6	/ð/-24	/f/-11
/f/-33	/r/-15	/v/-18	/w/-6	/b/-24	/ð/-10
/r/-31	/l/-14	/d/-17	/h/-5	/s/-16	/r/-9
/z/-25	/z/-13	/h/-16	/b/-5	/h/-16	/z/-9
/b/-23	/ð/-12	/k/-14	/ŋ/-5	/w/-16	/j/-7
/p/-12	/g/-9	/dʒ/-14	/k/-4	/l/-16	/d/-2
/g/-22	/j/-8	/ð/-12	/f/-4	/g/-8	/ŋ/-2
/h/-21	/h/-7	/ θ /-11	/s/-3	/f/-8	/k/-1
/m/-21	/p/-6	/g/-9	/g/-2	/r/-8	/g/-1
/ŋ/-17	/ θ /-5	/p/-8	/m/-2	/ θ /-8	/v/-1
/j/-17	/ʃ/-5	/ʃ/-7	/j/-2	/ʃ/-0	/ θ /-8
/θ/-8	/ŋ/-5	/b/-6	/ θ /-1	/tʃ/-0	/s/-1
/tʃ/-8	/b/-4	/tʃ/-4	/ʃ/-1	/ʒ/-0	/ʃ/-1
/ʃ/-6	/dʒ/-3	/j/-4	/tʃ/-1	/dʒ/-0	/m/-1
/dʒ/-6	/ʒ/-0	/ŋ/-2	/ʒ/-1	/ŋ/-0	/tʃ/-0
/ʒ/-0	/tʃ/-0	/ʒ/-0	/dʒ/-1	/j/-0	/ʒ/-0
/ʔ/-0	/ʔ/-0	/ʔ/-0	/ʔ/-0	/ʔ/-0	/ʔ/-0
Total: 659	Total: 280	Total: 428	Total: 133	Total: 386	Total: 240
Clusters: 179	Clusters: 68	Clusters: 108	Clusters: 35	Voiced fricative: 96	Clusters: 51
Voiceless stop: 131	Voiceless stop: 54	Nasal: 75	Voiced fricative: 27	Voiceless stop: 90	Liquid: 49
Voiceless fricative: 118	Voiceless fricative: 50	Voiced fricative: 69	Voiceless stop: 24	Voiced stop: 64	Voiceless stop: 44
Voiced fricative: 99	Voiced fricative: 44	Voiceless stop: 67	Liquid: 21	Voiceless fricative: 48	Voiceless fricative: 33
Voiced stop: 98	Voiced stop: 37	Liquid: 63	Voiced stop: 19	Nasal: 48	Voiced stop: 22
Nasal: 78	Nasal: 37	Voiceless fricative: 62	Nasal: 17	Clusters: 32	Voiced fricative: 20
Liquid: 66	Liquid: 29	Glide: 42	Voiceless fricative: 15	Liquid: 24	Glide: 1
Glide: 55	Glide: 26	Voiced stop: 32	Glide: 8	Glide: 16	Voiceless affricate: 0
Voiceless affricate: 8	Voiced affricate: 3	Voiced affricate: 14	Voiceless affricate: 1	Voiceless affricate: 0	Voiced affricate: 0
Voiced affricate: 6	Voiceless affricate: 0	Voiceless affricate: 4	Voiced affricate: 1	Voiced affricate: 0	Nasal: 0

involve the availability of external or internal visual or timing models guiding any motor act (Freeman, Cody, & Shady, 1993; Georgiou et al., 1993; Graybiel, 1998). For spontaneous speech, the speaker generates a novel action plan (the utterance) and executes and monitors the action using internal models. The burden of generating an action plan may also be great for recited speech, where the speaker generates an internal memorized pattern. In repetition and reading, an external model is provided, reducing the burden of planning, execution and monitoring for the speaker (Max, Guenther, Gracco, Ghosh, & Wallace, 2004). Numerous studies of analogous motor behaviors, involving gait and arm movement in persons with PD, have shown dramatically better organized gestures when an external model is provided (Georgiou, et al., 1994; Gracco & Abbs, 1987; Schenk, Baur, Stude, & Bötzel, 2003; Sheppard et al., 1996). For speaking, this model may also account for superior performance when a visual stimulus is provided (Hustad, Dardis, & McCourt, 2007).

Highly relevant to this task-dependent model of motor speech production are current perspectives on the functional properties of the basal ganglia and their relationship to cortical areas of control. The view of subcortical nuclei as a through-put station carrying out cortical commands has been radically revised (Alexander & Crutcher, 1990; Gurney, Prescott, & Redgrave, 2001; Marsden, 1982) and instead, the basal ganglia are known to constitute complex networks dedicated to planning, initiation, execution and management of motor behaviors. Of course, much remains unknown about the interrelationships between these multivarious subcortical operations (Eidelberg, 2007; Huang et al., 2007) and their relations with cortical control.

Our results for singing concur with Ludlow and Loucks (2003, p. 9): “Stuttering is a task specific disorder – that is, oral-motor dysfunction becomes apparent only during speech and not during humming, singing or chewing”. The brain scanning technique, functional magnetic resonance imaging data suggest that different neural structures underlie speech and singing (Ackermann & Riecker, 2004; Callan et al., 2006). The special status of singing in neurological conditions remains unexplained. Respiratory factors (Huber & Darling, 2011; Loucks, Poletto, Simonyan, Reynolds, & Ludlow, 2007) might account for improved voice and fluency performance in singing, which utilizes continuous phonation based on a more fluid air flow. For persons with severe developmental stuttering, vocal production while singing is commonly fluent (Luchsinger & Arnold, 1965; Fletcher, 1953) and a vocal mode related to singing, choral speech, is successfully utilized in stuttering therapy (Kalinowski & Saltuklaroglu, 2003; Packman, Onslow, & Menzies, 2000). Other observations imply that singing is modulated by the right hemisphere, because adult persons with aphasia due to left brain damage (Hébert, Racette, Gagnon, & Peretz, 2003; Hughlings Jackson, 1874 [1932]; Racette, Bard, & Peretz, 2006; Stahl, Kotz, Henseler, Turner, & Geyer, 2011) or left hemisphere removal (Burklund & Smith, 1977; Van Lancker & Cummings, 1999) can often sing familiar songs. In this study, the participant, who suffers from basal ganglia damage severely affecting motor speech, competently and fluently sang songs that he endorsed as familiar. Why damage to the basal ganglia spares lyrics produced during singing has hardly been addressed; preserved singing in this and other individuals with PD (Kempler & Van Lancker, 2002) is a tantalizing observation, possibly related to respiratory/phonatory coordination associated with brainstem structures.

In this study, dramatic evidence emerged that conversation, in contrast to other reading and repetition, was differentially affected, showing the greatest impact of the speech disability. Recitation was moderately affected. The small speech samples utilized in this task do not allow for definitive conclusions about recited speech. Studies concurrently underway reveal impaired recited speech in a larger group of persons with PD (Bridges, Van Lancker Sidtis, & Sidtis, 2012).

In summary, our results indicate that motor speech competence is influenced by speech task, from which we infer that spontaneous speech places the greatest burden on motor speech performance. These differential effects might reflect levels of motor and linguistic planning (Connor, Abbs, Cole, & Gracco, 1989). In this subject, phonetic and syllabic dysfluencies appeared across all tasks, reflecting motor planning of speech segments; however, lexical dysfluencies, likely reflecting linguistic planning, were more apparent in spontaneous speech, and polysyllabic lexical dysfluencies occurred only in the spontaneous and recited speech modes. The results for conversational and recited speech, as contrasted with repeated and read modes, may reflect the demands placed by internally generated and internal memorized models respectively (Alm, 2004). These results further support the notion that task effects for speech, as has been found for other motor behaviors, are associated with the degree of burden of internal motor action planning (Neilson & Neilson, 1987).

Clinical implications

Treatment implications of these findings for neurogenic acquired stuttering are limited, as the structured speech tasks, repetition and reading, do not provide functional vehicles for communication. However, it could be palliative to practice repetition and reading as a demonstration to the speech disordered person of his or her potential for relatively fluent speech. Measures that articulation during singing was the most fluent of all the tasks support the choral approach in stuttering treatment. For a trained or amateur singer with neurogenic acquired stuttering, karaoke practice may be beneficial.

A deficiency in formulaic expressions following subcortical damage or dysfunction has serious clinical implications for communicative function. Formulaic language, a major aspect of pragmatic competence, contributes considerably to the nuanced texture of normal conversational speech. The parkinsonian speaker may seem unengaged or uncooperative due to this deficiency in pragmatic competence. Therefore, both counseling and treatment may be appropriate. Persons with PD and their families may be informed that the circumstances of the disease lead to an abnormal impoverishment of speech formulas in conversation, so that misunderstandings are less likely to arise. Further, persons with PD can be shown exemplary conversational interactions in a treatment plan.

Finally, a case of acquired stuttering associated with PD was reported to be relieved by DBS unilaterally applied to the subthalamic nucleus (Walker et al., 2009), a treatment approach which has gained considerable prominence for PD. The study reported here is being pursued with functional brain imaging using positron emission tomography.

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References

Ackermann, H., & Riecker, A. (2004). The contribution of the insula to motor aspects of speech production: A review and a hypothesis. *Brain and Language*, *89*, 320–328.

Alexander, G. E., & Crutcher, M. D. (1990). Functional architecture of basal ganglia circuits: Neural substrates of parallel processing. *Trends in Neurosciences*, *3*, 266–271.

Alm, P. (2004). Stuttering and the basal ganglia circuits: A critical review of possible relations. *Journal of Communication Disorders*, *37*, 325–369.

Benke, Th., Hohenstein, C., Poewe, W., & Butterworth, B. (2000). Repetitive speech phenomenon in Parkinson's disease. *Journal of Neurology, Neurosurgery, and Psychiatry*, *69*, 319–324.

Boersma, P., & Weenink, D. (2005). Praat: Doing phonetics by computer (Version 4.3.01) [Computer program]. Retrieved from http://www.praat.org/

Bridges, K., & Van Lancker Sidtis, D. (2012). Formulaic language in Alzheimer's disease. Submitted for publication.

Bridges, K., Van Lancker Sidtis., D., & Sidtis, J. (2012). The role of the basal ganglia on production of recited speech: Effects of Parkinson's disease and DBS therapy. Submitted for publication.

Brown, A., & Docherty, G. J. (1995). Phonetic variation in dysarthric speech as a function of sampling task. *European Journal of Disorders of Communication*, *30*, 17–35.

Burklund, C. W., & Smith, A. (1977). Language and the cerebral hemispheres: Observations of verbal and nonverbal responses during 18 months following left ("dominant") hemispherectomy. *Neurology*, *27*, 627–633.

Caligiuri, M. P. (1989). The influence of speaking rate on articulatory hypokinesia in parkinsonian dysarthria. *Brain and Language*, *36*, 493–502.

Callan, D. E., Tsytsarev, V., Hanakawa, T., Callan, A. M., Katsuhara, M., Fukuyama, H., & Turner, R. (2006). Song and speech: Brain regions involved with perception and covert production. *NeuroImage*, *31*, 1327–1342.

Canter, G. J. (1971). Observations on neurogenic stuttering: A contribution to differential diagnosis. *British Journal of Disorders of Communication*, *6*, 139–143.

Canter, G. J., & Van Lancker, D. (1985). Disturbances of the temporal organization of speech following bilateral thalamic surgery in a patient with Parkinson's disease. *Journal of Communication Disorders*, *18*, 329–349.

Connor, N., Abbs, J., Cole, K., & Gracco, V. (1989). Parkinsonian deficits in serial multiarticulate movements for speech. *Brain*, *112*, 997–1009.

De Nil, L. F., Jokel, R., & Rochon, E. (2007). Etiology, symptomatology, and treatment of neurogenic stuttering. In E. G. Conture, & R. F. Curlee (Eds.), *Stuttering and related disorders of fluency* (pp. 326–343). New York: Thieme.

Dressler, W. U. (1975). Approaches to fast speech rules. In W. U. Dressler, & E. V. Mares (Eds.), *Phonologica* (pp. 219–234). München: Wilhelm Fink.

Duffy, J. (1995). *Motor speech disorders: Substrates, differential diagnosis, and management*. St Louis: Mosby.

Eidelberg, D. (2007). The assessment of neurological systems with functional imaging. *Brain and Language*, *102*, 192–199.

Fletcher, H. (1953). *Speech and hearing in communication*. New York: Van Nostrand.

Freeman, J. S., Cody, F. W., & Shady, W. (1993). The influence of external timing cues upon the rhythm of voluntary movements in Parkinson's disease. *Journal of Neurology Neurosurgery and Psychiatry*, *56*, 1078–1084.

Fry, D. B. (1947). The frequency of occurrence of speech sounds in southern English. *Archives Néerlandaises de Phonétique Experimentale*, *20*, 103–106.

Georgiou, N., Bradshaw, J. L., Iansek, R., Phillips, J. G., Mattingley, J. B., & Bradshaw, J. A. (1994). Reduction in external cues and movement sequencing in Parkinson's disease. *Journal of Neurology, Neurosurgery and Psychiatry*, *57*, 368–370.

Georgiou, N., Iansek, R., Bradshaw, J. L., Phillips, J. G., Mattingley, J. B., & Bradshaw, J. A. (1993). An evaluation of the role of internal cues in the pathogenesis of parkinsonian hypokinesia. *Brain*, *16*, 1575–1587.

Glover, H., Kalinowski, J., Rastatter, M., & Stuart, A. (1996). Effect of instruction to sing on stuttering frequency at normal and fast rates. *Perceptual and Motor Skills*, *2*, 511–522.

Gracco, V. L., & Abbs, J. (1987). Programming and execution processes of speech movement control: Potential neural correlates. In E. Killer, & M. Gopnik (Eds.), *Motor and sensory processes of language* (pp. 163–201). Hillsdale: Erlbaum.

Graybiel, A. M. (1998). The basal ganglia and chunking of action repertoires. *Neurobiology of Learning and Memory*, *70*, 119–136.

Gurney, K., Prescott, T. J., & Redgrave, P. (2001). A computational model of action selection in the basal ganglia. I. A new functional anatomy. *Biocybernetics and Biomedical Engineering*, *84*, 401–410.

Hébert, S., Racette, A., Gagnon, L., & Peretz, I. (2003). Revisiting the dissociation between singing and speaking in expressive aphasia. *Brain*, *126*, 1838–1850.

Helm-Estabrooks, N. (1999). Stuttering associated with acquired neurological disorders. In R. F. Curlee (Ed.), *Stuttering and related disorders of fluency* (pp. 255–268). New York: Thieme Medical Publishers.

Huang, C., Tang, C., Feigin, A., Lesser, M., Ma, Y., Pourfar, M., Dhawan, V., & Eidelberg, D. (2007). Changes in network activity with the progression of Parkinson's disease. *Brain*, *130*, 1834–1846.

Huber, J. E., & Darling, M. (2011). Effect of Parkinson's disease on the production of structured and unstructured speaking tasks: Respiratory physiologic and linguistic considerations. *Journal of Speech Language and Hearing Research*, *54*, 33–46.

Hughlings Jackson, J. 1874 [1932]. On the nature of the duality of the brain. In J. Taylor (Ed.), *Selected writings of John Hughlings Jackson* (vol. 2, pp. 129–145). London: Hodder & Stoughton.

Hustad, K. C., Dardis, C. M., & McCourt, K. A. (2007). Effects of visual information on intelligibility of open and closed class words in predictable sentences produced by speakers with dysarthria. *Clinical Linguistics and Phonetics*, *21*, 353–367.

Kalinowski, J., & Saltuklaroglu, T. (2003). Choral speech: The amelioration of stuttering via imitation and the mirror neuronal system. *Neuroscience Biobehavioral Review*, *27*, 339–347.

Kempler, D., & Van Lancker, D. (2002). The effect of speech task on intelligibility in dysarthria: Case study of Parkinson's disease. *Brain and Language*, *80*, 449–464.

Kent, R. (1994). *Reference manual for communicative sciences and disorders.* Austin, TX: Pro-Ed.

Kent, R. D., & Kent, J. F., (2002). Task-based profiles of the dysarthrias. *Folia Phoniatrica et Logopaedica*, *52*, 48–53.

Koller, W. C. (1983). Dysfluency (stuttering) in extrapyramidal disease. *Archives of Neurology*, *40*, 175–177.

Laan, G. P. M. (1997). The contribution of intonation, segmental durations, and spectral features to the perception of a spontaneous and a read speaking style. *Speech Communication*, *22*, 43–65.

Ladefoged, P. (2006). *A course in phonetics* (5th ed.) Boston, MA: Wadsworth.

Lebrun, Y., Leleux, Ch., & Retif, J. (1987). Neurogenic stuttering. *Acta Neurochirurgica (Wien)*, *85*, 103–109.

Loucks, T. M. J., Poletto, C. J., Simonyan, K., Reynolds, C. L., & Ludlow, C. L. (2007). Human brain activation during phonation and exhalation: Common volitional control for two upper airway functions. *NeuroImage*, *36*, 131–143.

Luchsinger, R., & Arnold, G. (1965). *Voice–Speech–Language*. Belmont, MA: Wadsworth Publishing Company.

Ludlow, C. L., & Loucks, T. (2003). Stuttering: A dynamic motor control disorder. *Journal of Fluency Disorders*, *28*, 273–295.

Lundgren, K., Helm-Estabrooks, N., & Klein, R. (2010). Stuttering following acquired brain damage: A review of the literature. *Journal of Neurolinguistics*, *23*, 447–454.

Marsden, C. (1982). The mysterious motor function of the basal ganglia: The Robert Wartenberg Lecture. *Neurology*, *32*, 514–539.

Max, L., Guenther, F. H., Gracco, V. L., Ghosh, S. S., & Wallace, M. E. (2004). Unstable or insufficiently activated internal models and feedback-biased motor control as sources of dysfluency: A theoretical model of stuttering. *Contemporary Issues in Communication Science and Disorders*, *31*, 105–122.

Miller, J. L., & Volaitis, L. E. (1989). Effect of speaking rate on the perceptual structure of a phonetic category. *Attention, Perception, and Psychophysics*, *46*, 505–512.

Mines, M., Hanson, B., & Shoup, J. (1978). Frequency of occurrence of phonemes in conversational English. *Language and Speech*, *21*, 221–242.

Neilson, M. D., & Neilson, P. D. (1987). Speech motor control and stuttering: A computational model of adaptive sensory-motor processing. *Speech Communication*, *6*, 325–333.

Packman, A., Onslow, M., & Menzies, R. (2000). Novel speech patterns and the control of stuttering. *Disability and Rehabilitation*, *22*, 65–79.

Perkins, W. F. (1990). What is stuttering? *Journal of Speech and Hearing Disorders*, *55*, 370–382.

Racette, A., Bard, C., & Peretz, I. (2006). Making non-fluent aphasics speak: Sing along! *Brain*, *129*, 2571–2584.

Rogers, T., Sidtis, D., & Sidtis, J. (2010). *Formulaic language production and comprehension in Alzheimer's and Parkinson's disease*. Paper presented at FLaRN, Paderborn, Germany, March, 2010.

Schenk, T., Baur, R., Stude, U., & Bötzel, K. (2003). Effects of deep brain stimulation on prehensile movements in PD patients are less pronounced when external timing cues are used. *Neuropsychologia*, *41*, 783–794.

Sheppard, D., Bradshaw, J. L., Phillips, J. G., Iansek, R., Cunnington, R., & Georgiou, N. (1996). Cuing of movement in Parkinson's disease. *Experimental Brain Research*, *144*, 8–16.

Sidtis, D., Cameron, K., Bonura, L., Sidtis, J. J. (2012). Speech intelligibility by listening in Parkinson speech with and without deep brain stimulation: Task effects. *Journal of Neurolinguistics*, *25*(2), 121–132.

Sidtis, D., Canterucci, G., & Katsnelson, D. (2009). Effects of neurological damage on production of formulaic language. *Clinical Linguistics and Phonetics*, *23*, 270–284.

Sidtis, D., Rogers T., Godier V. Tagliati M. & Sidtis J. J. (2010). Voice and fluency changes as a function of speech task and deep brain stimulation. *Journal of Speech Language and Hearing Research*, *53*, 1–11.

Sinclair, J. M. (1987). Collocation: A progress report. In R. Steele, & T. Threadgold (Eds.), *Language topics: Essays in honor of Michael Halliday, II* (pp. 319–331). Amsterdam: John Benjamins.

Sinclair, J. M. (1991). *Corpus, concordance, collocation.* Oxford: Oxford University Press.

Speedie, L. J., Wertman, E., T'air, J., & Heilman, K. M. (1993). Disruption of automatic speech following a right basal ganglia lesion. *Neurology*, *43*, 1768–1774.

Stahl, B., Kotz, S. A., Henseler, I., Turner, R., & Geyer, S. (2011). Rhythm in disguise: Why singing may not hold the key to recovery from aphasia. *Brain*, advance access published September 21, 1–11.

Theys, C., van Wieringen, A., & De Nil, L. F. (2008). A clinician survey of speech and non-speech characteristics of neurogenic stuttering. *Journal of Fluency Disorders*, *33*, 1–23.

Van Lancker, D. (1994). Nonpropositional speech in aphasia. In G. Blanken, J. Dittmann, J. Grimm, J. C. Marshall, & C.-W. Wallesch (Eds.), *Linguistic disorders and pathologies: An international handbook* (pp. 215–225). Berlin: Walter de Gruyter.

Van Lancker, D. (1998). Nonpropositional speech: Neurolinguistic studies. In A. Ellis (Ed.), *Progress in the psychology of language* (pp. 49–118). Hillsdale: Lawrence Erlbaum.

Van Lancker, D., & Cummings, J. L. (1999). Expletives: Neurolinguistic and neurobehavioral inquiries into swearing. *Brain Research Review*, *31*, 81–104.
Van Lancker, D., & Rallon, G. (2004). Tracking the incidence of formulaic expressions in everyday speech: Methods for classification and verification. *Language and Communication*, *24*, 207–240.
Van Lancker, D., McIntosh, R., & Grafton, R. (2003). PET activation studies comparing two speech tasks widely used in surgical mapping. *Brain and Language, 85*, 245–261.
Van Lancker Sidtis, D. (2004). When novel sentences spoken or heard for the first time in the history of the universe are not enough: Toward a dual-process model of language. *International Journal of Language and Communication Disorders, 39*(1), 1–44.
Van Lancker Sidtis, D. (2010). Formulaic and novel expressions in mind and brain: Empirical studies and a dual process model of language competence. In J. Guendouzi, F. Loncke, & M. Williams (Eds.), *The handbook of psycholinguistic & cognitive processes: Perspectives in communication disorders* (pp. 247–272). London: Taylor & Francis.
Van Lancker Sidtis, D. (2012). Two track mind: Formulaic and novel language support a dual process model. In M. Faust (Ed.), *Advances in the neural substrates of language: Toward a synthesis of basic science and clinical research* (pp. 342–367). London: Blackwell Publishing Ltd.
Van Lancker Sidtis, D. (in press). Formulaic language and language disorders. *Annual Review of Applied Linguistics*.
Van Lancker Sidtis, D., & Postman, W.A. (2006). Formulaic expressions in spontaneous speech of left- and right-hemisphere damaged subjects. *Aphasiology*, *20*, 411–426.
Van Lancker Sidtis, D., Pachana, N., & Cummings, J., & Sidtis, J. (2006). Dysprosodic speech following basal ganglia insult: Toward a conceptual framework for the study of the cerebral representation of prosody. *Brain and Language*, *97*, 135–153.
Walker, H. C., Phillips, D. E., Boswell, D. B., Guthrie, B. L., Guthrie, S. L., Nicholas, A. P., Montgomery, E. B., & Watts, R. L. (2009). Relief of acquired stuttering associated with Parkinson's disease by unilateral left subthalamic brain stimulation. *Journal of Speech, Language, and Hearing Research*, *52*, 1652–1657.
Wray, A., & Perkins, M. (2000). The functions of formulaic language: An integrated model. *Language and Communication*, *20*, 1–28.
Yorkston, K. M., Beukelman, D. R., & Bell, K. R. (1988). *Clinical management of dysarthric speakers*. Boston, MA: College-Hill Press.
Zeplin, J., & Kent, R. D. (1996). Reliability of auditory-perceptual scaling of dysarthria. In D. Robin, K. Yorkston, & D. R. Beukelman (Eds.), *Disorders of motor speech: Recent advances in assessment, treatment, and clinical advantages in assessment, treatment, and clinical characterization* (pp. 145–154). Baltimore, MD: Brookes.

Appendix 1. Examples of speech tasks

Conversation sample

Yes I was a photographer for 33 years and I did still life photography large camera work. I had a studio staff of eight uh uh five ffff then four then three then two then one. And then the thethe business folded after 33 the thethethethethethethethe 33 years.

Conversation–repetition sample

It's like having two kids all o-over again
Do you remember what she said
It never came into play
For the rest of the year
Go fishing
I play with the grandson more

Recited speech sample

Mary had a little lamb
And it's fleece was white-ite as snow
'N everywhere that Mary went
The lamb was sure to go

Reading sample

When the sunlight strikes raindrops in the air they act as a prism and form a rainbow. A rainbow is a division of white light into many beautiful colors. These tay the thethe these these the these take the shape of a long round arch.

Sentence repetition sample

Some boys can find the way back home.
Top pops did mails Doug's keys on Thursday.
Will he never vizz zoo?
Could Sue give pancakes to the boys?

Singing sample

Happy Birthday to you
Happy Birthday to you
Happy Birthday dear Mozart
Happy Birthday to you