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The impact of Parkinson's disease on vocal-prosodic communication from the perspective of listeners

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Abstract

An expressive disturbance of speech prosody has long been associated with idiopathic Parkinson's disease (PD), but little is known about the impact of dysprosody on vocal-prosodic communication from the perspective of *listeners*. Recordings of healthy adults ($n = 12$) and adults with mild to moderate PD ($n = 21$) were elicited in four speech contexts in which prosody serves a primary function in linguistic or emotive communication (phonemic stress, contrastive stress, sentence mode, and emotional prosody). Twenty independent listeners naive to the disease status of individual speakers then judged the intended meanings conveyed by prosody for tokens recorded in each condition. Findings indicated that PD speakers were less successful at communicating stress distinctions, especially words produced with contrastive stress, which were identifiable to listeners. Listeners were also significantly less able to detect intended emotional qualities of Parkinsonian speech, especially for *anger* and *disgust*. Emotional expressions that were correctly recognized by listeners were consistently rated as less intense for the PD group. Utterances produced by PD speakers were frequently characterized as sounding *sad* or devoid of emotion entirely (*neutral*). Results argue that motor limitations on the vocal apparatus in PD produce serious and *early* negative repercussions on communication through prosody, which diminish the social-linguistic competence of Parkinsonian adults as judged by listeners.

Keywords: Parkinson's disease; Communication; Speech; Prosody; Emotion; Listener impressions

1. Introduction

Abnormalities of expressive language in patients with Parkinson's disease (PD) have long been identified as a consequence of dopamine insufficiency within the basal ganglia, which progressively limits muscular control of the larynx, the oral cavity, and other physiological support mechanisms for speech (Canter, 1965b; Critchley, 1981; Cummings, Darkins, Mendez, Hill, & Benson, 1988; Darkins, Fromkin, & Benson, 1988; Kegl, Cohen, & Poizner, 1999). These limitations have serious, negative repercussions on the speaking voices of Parkinsonian adults which display abnormalities in articulation, nasality, voice quality, and in the *prosodic* or "melodic" features of their utterances (Canter, 1965b; Darley, Aronson, & Brown, 1975).

The effects of PD on prosodic characteristics of their spoken language, and the potential impact of these abnormalities on communication partners, are of principal concern in this investigation. Prosody refers to relative changes in the fundamental frequency (pitch), intensity (loudness), and duration (rate/tempo) of speech. These features are combined and exploited by speakers to communicate their emotions and attitudes to listeners, for example, whether the speaker is feeling "happy" or "frustrated." At the same time, these parameters may encode linguistically meaningful distinctions in the speech signal, such as: (1) "phonemic" stress, or local word features which allow listeners to understand the semantic differences between "HOTdog" (the food) and "hot DOG" (an animal which is

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hot); (2) contrastive stress, or local cues which mark the pragmatic salience of particular words or information content within an utterance to the listener (e.g., "The TEACHER arrived late" versus "The teacher arrived LATE"); and (3) "sentence mode," or cues at the end of an utterance such as "Mary read the book" which mark it as a factual statement or a question for clarification directed to the listener.

General acoustic descriptions of Parkinsonian speech reveal that it exhibits less variability in fundamental frequency (i.e., "monopitch") and intensity (i.e., "monoloudness"), as well as characteristic abnormalities in speech rate and pausing, than speech produced by healthy, aging adults (Canter, 1963; Harel, Cannizzaro, Cohen, Reilly, & Snyder, 2004; Illes, 1989; Kegl et al., 1999; Kent & Rosenbek, 1982). These aberrant vocal parameters, which appear to emerge very early in the disease process (Harel et al., 2004), promote a critical lack of "acoustic contrast or detail" in Parkinsonian speech (Kent & Rosenbek, 1982) which likely contributes to overall reductions in speech intelligibility (Kempler & Van Lancker, 2002).

However, despite a consensus that dysprosody is a persistent, negative feature that affects communication in PD, the ability of these patients to modulate prosodic attributes to convey specific affective or linguistic meanings in their speech has been investigated very little and only in highly selective contexts (Blonder, Gur, & Gur, 1989; Caekebeke, Jennekens-Schinkel, van der Linden, Buruma, & Roos, 1991; Darkins et al., 1988; Le Dorze, Dionne, Ryalls, Julien, & Ouellet, 1992; Penner, Miller, Hertrich, Ackermann, & Schumm, 2001; Scott, Caird, & Williams, 1984). Given the strong likelihood that prosodic abnormalities alter listeners' *perceptions* of the social and linguistic competence of PD speakers in a negative manner (McNamara & Durso, 2003; Pitcairn, Clemie, Gray, & Pentland, 1990), the ability of Parkinsonian adults to communicate meaning successfully at the prosodic level merits detailed scrutiny.

Darkins et al. (1988), for example, reported significant pitch and timing (pause) irregularities in the production of phonemic stress pairs (e.g., GREENhouse vs. green HOUSE) when produced by 30 PD relative to 15 healthy speakers, although these patients could accurately identify the same concepts from prosodic cues in a perception task (see also Lloyd, 1999; Pell, 1996 for data on perception). The production of words bearing *contrastive* stress also displayed acoustic abnormalities in the relative height and timing of underlying pitch accents when produced by PD speakers (Penner et al., 2001), and in a separate study, these focussed words were perceived as significantly less "intense" by two naive listeners when elicited from PD as opposed to healthy speakers (Blonder et al., 1989). When required to produce a high/rising intonation contour that signals a question, several reports have demonstrated that PD speakers are impaired in the acoustic (Kegl et al., 1999; Le Dorze et al., 1992; Penner et al., 2001) and perceptual (Blonder et al., 1989) adequacy of these linguistic expressions, despite normal capacity to produce the same utterances with a declarative (falling) intonation contour (Blonder et al., 1989; Caekebeke et al., 1991; Penner et al., 2001; Scott et al., 1984). Finally, there is some evidence that the ability of PD speakers to convey *emotional* meanings through prosody is perceived as aberrant by listeners independent of the patient's depression or medication status (Benke, Bosch, & Andree, 1998; Blonder et al., 1989), especially when the communication of "anger" is investigated (Caekebeke et al., 1991; Penner et al., 2001; Scott et al., 1984). Listeners judge Parkinsonian individuals to be more "cold," "anxious," "unhappy," and less "likeable" than healthy adults based on impressions formed strictly from their speaking voices (Pitcairn et al., 1990), findings which are also likely to index a failure to modulate affective features of prosody appropriately in PD.

Collectively, these findings reinforce that a disorder of prosody "is intrinsic to Idiopathic Parkinson's disease" (Darkins et al., 1988) and that it represents an important social determinant of their health status, affecting how listeners *perceive* their communicative intentions in a potentially misleading and deleterious manner. What is lacking in the research is a coherent portrait of how PD influences the efficacy of prosodic communication in linguistic and affective speech contexts, as determined by a robust and independent group of naive listeners; previous perceptual studies have relied exclusively on the impressions of 2–3 "expert" listeners to make claims about speech characteristics in PD (Benke et al., 1998; Blonder et al., 1989; Caekebeke et al., 1991; Scott et al., 1984). Achieving a comprehensive survey of prosodic communication in PD will inform issues of the linguistic and emotional adequacy of Parkinsonian speech in vocal expression, will speak to some of the negative social impressions drawn by listeners who encounter Parkinsonian speakers (Pitcairn et al., 1990), and will help quantify self-report measures indicating that both PD patients and their family members consider prosodic communication as "inappropriate" and a major problem area that affects their social relationships (McNamara & Durso, 2003). It was hypothesized that prosodic insufficiencies in PD speakers compared to healthy speakers would contribute to significantly greater errors in how listeners identified both linguistic and affective meanings of prosody for the patient group, especially when prosodic meanings are signalled by relatively large pitch excursions or prominent pitch/intensity cues in the accent structure of speech (Canter, 1963; Harel et al., 2004; Kent & Rosenbek, 1982; Penner et al., 2001).

2. Methods

2.1. Speakers

Vocal stimuli were elicited from 21 English-speaking adults with idiopathic PD and 12 healthy control (HC) subjects. Diagnosis of idiopathic PD was confirmed by the residing neurologist based on accepted motor criteria

(Calne, Snow, & Lee, 1992) and these participants were tested an average of 3.5 years post-diagnosis. All patients presented with mild-moderate motor impairment according to Hoehn and Yahr and Unified Parkinson's Disease Rating Scale (UPDRS) motor criteria. Motor signs in the PD group were characterized as right dominant ($n = 7$), left dominant ($n = 11$), and bilateral ($n = 3$). All but one of the patients was medicated during testing, as follows: carbidopa/L-dopa ($n = 17$), d2-agonist ($n = 11$), MAO-B inhibitor ($n = 1$), COMT inhibitor ($n = 1$), amantadine ($n = 3$), and anticholinergics ($n = 1$). One patient was also following a course of paroxetine, an antidepressant. All patients were recruited through the Baycrest Centre for Geriatric Care in Toronto, Canada. No patient had a history of substance abuse, presented with any major medical or neurological difficulties other than PD (e.g., stroke) or had undergone major surgical interventions related to PD.

Prior to testing, the investigators verified the absence of dementia on the basis of results from the Mattis Dementia Rating Scale. Absence of language impairment (aphasia) was indicated by a speech-language pathologist as derived from medical records. A general index of speech intelligibility for individual speakers within the PD group was obtained by eliciting a continuous language sample from each participant (picture description task) and then having each sample rated by an experienced speech-language pathologist and two student clinicians (De Bodt, Hernandez-Diaz Huici, & Van de Heyning, 2002). Each rater categorized the intelligibility of each Parkinsonian speaker on a four-point scale ranging from 0 ("normal–completely undisturbed") to 3 ("clear and severe disorder"). An inter-rater consensus of 85% was obtained across the 21 speakers, with no instances where at least two of the three raters were not in agreement. All members of the PD group performed high on the intelligibility scale and received an average rating which fell between "0" ("normal–completely undisturbed") and "1" ("slight but notable disorder"), indicating that this dimension was not highly disturbed in the patient group overall. Specifically, 12 patients were rated as "completly undisturbed" by all three raters, seven patients were judged to have normal intelligibility by 2/3 of the raters, and two patients (PD9, PD13) were characterized with a "slight but notable" disorder by 2/3 raters.

The PD and HC groups were matched in years for age (PD: $M = 61.7$, $SD = 8.6$; HC: $M = 62.8$, $SD = 3.1$) and formal education (PD: $M = 16.4$, $SD = 3.7$; HC: $M = 15.7$, $SD = 3.1$). All participants in the production study were screened for the presence and severity of depression via the Hamilton Depression Inventory (Short Form). As well, each participant passed a puretone audiometric screening to ensure acceptable hearing thresholds for frequencies critical to speech comprehension (minimum 30 db HL at 0.5, 1, and 2 kHz, for the better ear). A summary of speaker characteristics can be found in Table 1.

Table 1
Demographic and clinical features of speakers with Parkinson's disease (PD) and healthy control (HC) speakers (mean ± *SD*)

Variable	Patients with PD ($n = 21$)	Healthy controls ($n = 12$)
Sex (f/m)	10/11	6/6
Age (years)	61.7 ± 8.6	62.8 ± 7.1
Education (years)	16.0 ± 3.7	15.7 ± 3.1
Disease duration (years)	3.9 ± 1.9	N/A
Hoehn and Yahr rating score	2.0 ± 0.5	N/A
Motor UPDRS	14.5 ± 7.1	N/A
Mattis Dementia Rating Scale[a]	141.2 ± 2.1	142.6 ± 1.9
Hamilton Depression Inventory[b]	4.7 ± 3.4	2.6 ± 3.4

[a] Total score, maximum = 144.
[b] Short form, maximum = 33, increased scores indicate greater impairment.

2.2. Speech production tasks

Each speaker completed a series of four production tasks in which he or she produced differences in phonemic stress, contrastive stress, sentence mode, and emotional prosody. Production tasks were administered in a fixed random order to all speakers, who were recorded individually in a quiet testing room during a single session. Each task was preceded by a set of practice items to familiarize the speaker with task instructions and the recording procedure. Target utterances were captured onto digital audiotape by a high-quality, head-mounted microphone and then copied onto a computer (down-sampled to 24 kHz, 16 bit, mono) for editing and preparation of listening tasks. The stimuli and procedure for each of the four production tasks was the following:

(a) *Phonemic stress.* To assess whether speakers could use prosody to encode differences in phonemic (lexical) stress, each speaker was shown a series of pictures depicting noun compound (e.g., HOTdog, the food) or noun phrase (e.g., hot DOG, a dog that feels hot) interpretations of word pairs that differed in syllable stress placement. Speakers communicated the meaning of the picture verbally using the declarative form "this is a _ (e.g., HOTdog)". Sixteen tokens (i.e., eight word pairs) were recorded from each speaker.
(b) *Contrastive stress.* To evaluate whether speakers could highlight the semantic importance of information in their utterances using prosody, each speaker was required to emphasize "keywords" located in first, middle, or last position of target sentences. Speakers were presented a series of two sentence narratives (e.g., "The *girl jumped* on the *bed*. The *boy sat* on the *steps.*" Keyword positions are indicated here in italics). The narratives were printed on a card in large print and then read aloud by the examiner. Following the narrative, speakers responded to questions from the examiner which required them to produce contrastive stress on one of the three keywords (e.g., Did the *boy* or the *girl* jump on the bed? Target response:

The *girl* jumped on the bed.). Each speaker produced 18 target sentences in total (3 keyword positions × 6 tokens).

(c) *Sentence mode*. To evaluate whether speakers could produce differences in sentence intonation, target sentences from the contrastive stress production task were shown to the speaker and simultaneously read out loud by the examiner. Speakers were required to repeat the sentence in the form of a question without altering the word order. Twelve (12) tokens were recorded from each speaker.

(d) *Emotional prosody*. To determine if speakers could express different emotions through their voice, they were required to produce sentences in each of six distinct affective tones (angry, disgusted, happy, neutral, sad, and surprised). Speakers were shown the target sentence on a card, were encouraged to read it silently, and then produce the sentence with the intended emotion in a manner "that if someone listened to their recording they would know what emotion the speaker was expressing." There were six target sentences for each emotion, and all recordings for a given emotion were elicited before proceeding to the next emotion (the order of emotions was randomized). In addition, for each emotion half of the utterances were semantically consistent with the intended emotional tone with respect to the verbal content ("biased" condition: e.g., "You burnt me with your cigarette" spoken in an angry tone), whereas half of the tokens were semantically neutral with respect to the content ("unbiased" condition: e.g., "They found it in the room" spoken in an angry tone). For productions of "neutral" emotion, all six target sentences were semantically unbiasing (e.g., "The hat was brown") to avoid conflicts between prosody and verbal information in all target utterances. Each speaker produced 36 emotional utterances in total (6 emotions × 6 tokens).

2.3. Listeners

A group of 10 female and 10 male native English-speaking adults was recruited through campus advertisements to judge the accuracy of prosodic meanings produced by each speaker group in the four prosody conditions. The listener group had a mean age of 23.8 years (±8.1) and a mean education of 15.6 years (±1.5 years). Listeners were paid a small amount (CAD$30) following their participation.

2.4. Prosody identification tasks

Due to the large volume of recordings obtained for each subject—necessary for conducting detailed acoustic analyses, see Cheang and Pell (2004)—only a subset of items generated for each production task was selected as stimuli to enter into four corresponding perceptual identification tasks. For these randomly selected items, a small number of tokens that contained recording artifacts (e.g., tape hiss) or in which speakers altered the target wording was discarded. All remaining tokens, as enumerated below, were then entered into a separate perceptual experiment for each prosody condition using SuperLab presentation software (Cedrus, USA). Blocks within each task were quasi-randomly constructed of approximately 33–38 trials which intermixed productions from PD and HC speakers according to their relative ratio in the study, and with respect to task-specific variables (e.g, stress location, emotion type). Speech stimuli were presented to individual listeners over headphones from a laptop computer at a comfortable listening level in a quiet laboratory. Each task began with detailed instructions and a block of practice trials to familiarize the participant with task goals and with the different voices they would be hearing, and all responses were recorded by the computer. The four tasks were defined as follows:

(a) *Phonemic stress*. Each listener was presented three of the noun compound/noun phrase pairs produced by each speaker. These sentences always began with the carrier phrase, "This is a…" and ended with the intended noun compound or noun phrase word meaning. Two pictures which corresponded to each of the possible interpretations of the final word were presented side-by-side on a computer screen as listeners were presented each utterance. Utterances were fully intermixed and randomized across speakers and the orientation of pictures was also alternated across trials. Participants used a mouse click to specify which picture matched the meaning of the final target word in the utterance, and the accuracy of these judgements was examined.

(b) *Contrastive stress*. Each listener was presented nine utterances produced by each speaker (3 items × 3 stress positions). As they listened to the utterance, they were shown the sentence visually on a computer screen with the three keyword positions underlined and numbered. Listeners indicated which word in the sentence was produced with greatest emphasis (first, middle, and last) by clicking on the corresponding word on the computer screen. If listeners judged that none of the words was being emphasized by the speaker, they were asked to choose "none" at the bottom of the computer screen. The accuracy and nature of the judgement was assessed.

(c) *Sentence mode*. Each listener was presented six utterances produced by each speaker, three as a statement and three as a question. Because the same sentence targets were used in the contrastive stress and sentence mode production tasks, statements produced by each speaker were identified by selecting corresponding target items elicited in the contrastive stress task (bearing emphasis in different locations) which had not been entered into the contrastive stress identification task. Following presentation of each utterance, the listener indicated whether the sentence was a statement or a question by clicking on a corresponding label displayed on the computer screen. Response accuracy was measured.

(d) *Emotional prosody*. Each listener was presented 32 utterances produced by each speaker, representing six items produced in each of the five emotional modes (anger, disgust, happiness, sadness, and surprise) and two randomly selected neutral sentences. Expressions of all emotions were fully intermixed and randomized within a series of blocks. Immediately after each trial, the participant was required to choose which of the six emotions (anger, disgust, happiness, sadness, surprise, and neutral) was conveyed by the utterance by clicking on a corresponding emotion label on the computer screen. Following the emotion judgement, participants were then required to make a secondary decision about the perceived *intensity* of the emotion selected in reference to a visual rating scale which appeared on the monitor. Subjects clicked on a number between one and five, where "1" denotes that the identified emotion was weakly conveyed and "5" indicates that it was very strongly conveyed by the speaker. In those instances when the listener indicated "neutral" as the selected emotion, there was no secondary judgement of emotional intensity and the experiment advanced to the subsequent trial. The accuracy and nature of the emotion selected and its perceived intensity were recorded by the computer.

2.5. Statistical procedures

Listener identification judgements of the prosodic meanings expressed by each speaker group were analyzed separately by task using mixed-design analyses of variance (ANOVA). Given our primary interest in generalizing how well normal listeners identify meaningful differences from prosody as a function of PD disease status, speaker group (PD, HC) was treated as a fixed variable in these analyses. Data analyses pertaining to the Phonemic stress, Contrastive stress, and Sentence mode tasks focused on the proportion of errors made when listening to PD versus HC speakers under the influence of specific task parameters. For the Emotional Prosody task, distinct analyses considered two dependent measures: the proportion of listener errors to identify the intended emotion of the speaker in two conditions of verbal-semantic bias with respect to the prosodic emotion; and listener intensity ratings of these emotions when their identification judgements were *correct*. In all cases that warranted post hoc analyses, significant interactions were examined using the Tukey Honestly Significant Difference (HSD) method (Tukey $\alpha = 0.05$). Effect size was computed, where prescribed, according to Rosenthal (1991).

3. Results

Table 2 summarizes the listeners' error judgements for the three linguistic prosody identification tasks (phonemic stress, contrastive stress, and sentence mode) as an index of speaker group and relevant prosodic stimulus features.

Table 2
Mean proportion of listener errors in the three linguistic prosody identification tasks when judging stimuli produced by speakers with Parkinson's disease (PD) and healthy control (HC) speakers

Task	Component identified by listener	Speaker group	
		PD	HC
Phonemic stress identification	Noun compound	0.39 (0.09)	0.38 (0.06)
	Noun phrase	0.59 (0.06)	0.53 (0.08)
Contrastive stress identification	Initial stress	0.42 (0.17)	0.25 (0.20)
	Middle stress	0.36 (0.10)	0.17 (0.12)
	Final stress	0.75 (0.12)	0.53 (0.13)
Sentence mode identification	Question	0.14 (0.05)	0.07 (0.07)
	Statement	0.02 (0.04)	0.09 (0.05)

Standard deviations are in parentheses.

3.1. Phonemic stress identification

The mean proportion of errors made by the 20 listeners in identifying the meaning of phonemic stress pairs was subjected to a 2×2 repeated measures ANOVA involving SPEAKER GROUP (PD, HC) and NOUN TYPE (noun compound, noun phrase). The main effect of NOUN TYPE was significant ($F(1,19) = 43.57$, $p < .001$, $r = .83$), which was explained post hoc by the fact that listeners were better at identifying noun compounds than noun phrases in this task overall. More importantly, a significant main effect for SPEAKER GROUP ($F(1,19) = 13.75$, $p < .001$, $r = .65$) was yielded by this analysis, indicating that listeners misidentified the intended meaning of words produced by the PD speakers significantly more often than words produced by healthy speakers overall. The interaction was not significant ($p = .12$).

3.2. Contrastive stress identification

Two sets of analyses were applied to the results of this task. First, the mean listener errors for identifying the sentential location of contrastive stress were analyzed in a 2×3 repeated measures ANOVA, with independent factors of SPEAKER GROUP (PD, HC) and STRESS POSITION (initial, middle, and final). A significant main effect emerged for STRESS POSITION ($F(2,38) = 127.59$, $p < .001$); listeners were least accurate at identifying sentence-final emphasis, followed by sentence-initial emphasis, with fewest errors for identifying middle emphasis (all comparisons differed significantly). Of greater interest, there was a significant main effect of SPEAKER GROUP ($F(1,19) = 233.34$, $p < .001$, $r = .96$). Content words emphasized by the PD speakers were generally less recognizable by listeners than those produced by the HC speakers, promoting greater errors when listening to the patient group. No interaction arose from the analysis ($p = .15$).

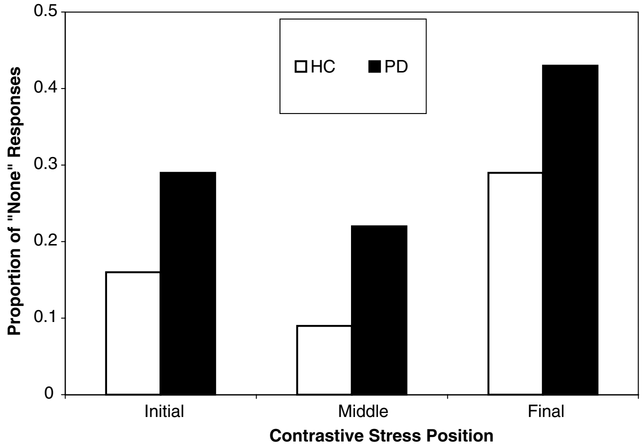

Fig. 1. Proportion of "None" responses assigned by the group of 20 listeners when required to identify the position of contrastive stress in sentences produced by speakers with Parkinson's disease (PD) and healthy control (HC) speakers.

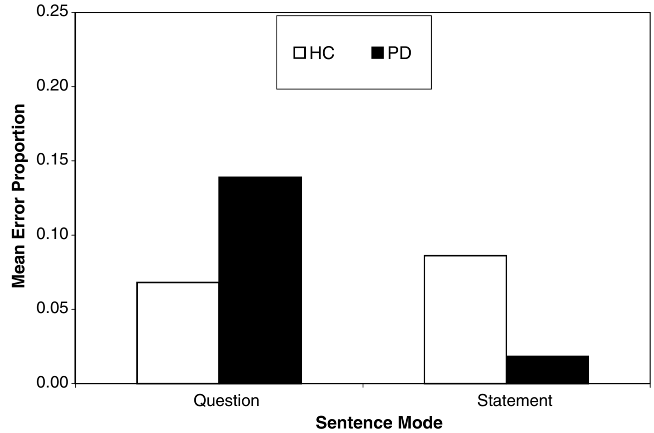

Fig. 2. Proportion of utterances for which listeners misidentified the intended sentence mode when produced by speakers with Parkinson's disease (PD) and healthy control (HC) speakers.

A secondary analysis was performed strictly on the proportion of "none" responses assigned by listeners when they judged that no words were being emphasized by PD or HC speakers (these responses were treated as one potential source of errors in the initial analysis, but were isolated here to qualify the nature of listeners' identification judgments further). Results of the SPEAKER GROUP × STRESS POSITION (2 × 3) ANOVA performed on the "none" responses mirrored those of the first analysis: significant effects were observed for STRESS POSITION ($F(2,38) = 54.12$, $p < .001$) and SPEAKER GROUP ($F(1,19) = 127.19$, $p < .001$, $r = .93$). Post hoc elaboration of the SPEAKER GROUP effect revealed that the listeners more frequently interpreted utterances produced by PD speakers as lacking any emphasized words than utterances produced by HC speakers, a pattern that was not dependent on the intended word position of the emphasized word ($p = .77$ for the interaction). The extent to which productions by each group sounded emphatically "neutral" to listeners is shown in Fig. 1.

3.3. Sentence mode identification

Mean listener errors for identifying the declarative/interrogative sentence mode were subjected to a 2 × 2 repeated ANOVA involving SPEAKER GROUP (PD, HC) and SENTENCE MODE (Question, Statement). This analysis yielded a significant main effect of SENTENCE MODE ($F(1,19) = 26.36$, $p < .001$, $r = .76$) and a significant SPEAKER GROUP × SENTENCE MODE interaction ($F(1,19) = 101.23$, $p < .001$, $r = .92$). The interaction was explained post hoc by the observation that PD speakers were less successful than HC speakers at conveying questions to listeners; the productions of PD speakers were more frequently identified as statements irrespective of whether a question or statement was intended, as illustrated in Fig. 2.

3.4. Emotional prosody identification

Listener identification errors and intensity ratings are summarized together in Table 3, according to speaker group, emotion type, and biasing condition.

3.4.1. Identification errors

A series of five 2 × 2 ANOVAs involving SPEAKER GROUP (PD, HC) and SEMANTIC BIAS (biased, unbiased) was run to evaluate identification errors corresponding to each discrete emotion type separately. Results of these ANOVAs yielded a significant main effect for SEMANTIC BIAS for four of the five emotions: anger ($F(1,19) = 195.75$, $p < .001$, $r = .95$); disgust ($F(1,19) = 123.47$, $p < .001$, $r = .93$); happiness ($F(1,19) = 75.99$, $p < .001$, $r = .89$); and sadness ($F(1,19) = 51.72$, $p < .001$, $r = .86$). With the exception of *surprise*, Tukey's comparisons established that listeners were always more accurate in identifying the intended vocal emotion of speakers when

Table 3
Listeners' impressions of emotional prosody by speakers with Parkinson's disease (PD) and healthy control (HC) speakers, in reference to: the mean proportion of target recognition errors; and the mean intensity of correctly identified emotions (on a 5-point scale of increasing intensity, scale = 1–5)

Emotion	Verbal-semantic content	Identification errors		Intensity ratings	
		PD	HC	PD	HC
Angry	Biased	0.18 (0.10)	0.09 (0.07)	3.07 (0.40)	3.74 (0.48)
	Unbiased	0.72 (0.13)	0.49 (0.14)	2.68 (0.53)	2.98 (0.43)
Disgust	Biased	0.31 (0.21)	0.30 (0.19)	3.20 (0.47)	3.44 (0.43)
	Unbiased	0.85 (0.10)	0.78 (0.11)	2.63 (0.70)	3.06 (0.63)
Happy	Biased	0.30 (0.15)	0.23 (0.13)	2.67 (0.42)	3.06 (0.59)
	Unbiased	0.53 (0.15)	0.51 (0.13)	2.71 (0.48)	2.87 (0.49)
Sad	Biased	0.18 (0.12)	0.24 (0.12)	3.03 (0.56)	2.96 (0.57)
	Unbiased	0.48 (0.17)	0.49 (0.16)	2.72 (0.53)	2.78 (0.51)
Surprise	Biased	0.54 (0.15)	0.54 (0.16)	3.25 (0.43)	3.62 (0.49)
	Unbiased	0.51 (0.10)	0.58 (0.13)	3.28 (0.48)	3.45 (0.56)

Standard deviations are in parentheses.

the verbal-semantic content of sentences further biased the listener toward the emotional meaning (as opposed to when the verbal content was unbiased or "semantically neutral"). Significant main effects of SPEAKER GROUP were also uncovered for all five emotions studied: anger ($F(1,19) = 130.40$, $p < .001$, $r = .93$); disgust ($F(1,19) = 12.04$, $p = .003$, $r = .62$); happiness ($F(1,19) = 8.09$, $p = .01$, $r = .55$); sadness ($F(1,19) = 5.15$, $p = .04$, $r = .46$); and surprise ($F(1,19) = 7.97$, $p = .01$, $r = .54$). Relative to the HC speakers, PD speakers were generally less successful at conveying these emotions to listeners, although with the exception of *happiness*, these main effects were qualified by a significant interaction of SPEAKER GROUP × SEMANTIC BIAS for: anger ($F(1,19) = 26.72$, $p < .001$, $r = .76$); disgust ($F(1,19) = 5.49$, $p = .03$, $r = .47$); sadness ($F(1,19) = 7.50$, $p = .01$, $r = .53$); and surprise ($F(1,19) = 7.90$, $p = .01$, $r = .54$).

Post hoc analyses of the interactions indicated that regardless of whether sentences were semantically biased or not, PD speakers were always significantly less able to convey *anger* to listeners than healthy speakers. In addition, when sentences did not contain semantically biassing information (i.e., only prosodic cues signalled the intended emotion), listeners were less able to recognize *disgust* from Parkinsonian as opposed to healthy speech. Listeners were more accurate in recognizing *sadness*, and curiously, *surprise* from the speech produced by PD relative to HC speakers in selective bias conditions (i.e., from semantically biased and semantically unbiased utterances, respectively).

A secondary analysis of the errors sought to qualify how frequently utterances produced by each speaker group tended to sound affectively "neutral" to listeners by isolating this source of their misidentifications irrespective of bias type (data were collapsed across levels of bias within each emotion). The proportion of incorrect "neutral" responses assigned to each SPEAKER GROUP (PD, HC) and for each EMOTION (anger, disgust, happiness, sadness, and surprise) was examined directly within a single 2×5 repeated measures ANOVA. This analysis produced significant main effects for SPEAKER GROUP ($F(1,19) = 35.61$, $p < .001$, $r = .81$) and EMOTION ($F(4,76) = 18.26$, $p < .001$), and a significant interaction of these two factors ($F(4,76) = 10.32$, $p < .001$). Post hoc comparisons indicated that listeners were more likely to interpret speech which was intended to convey anger, happiness, and surprise as sounding "neutral" when produced by the members of the PD group as opposed to the HC group. The extent to which emotional utterances produced by members of each speaker group sounded "neutral" to listeners, or without obvious emotional qualities, is presented in Fig. 3A.

3.4.2. Intensity ratings

To understand whether emotions that listeners *correctly* recognized for each speaker group were perceived differently in the intensity of these expressions, a single 2×5 ANOVA with factors of SPEAKER GROUP (PD, HC) repeated across EMOTION (anger, disgust, happiness, sadness, and surprise) was performed on the mean intensity ratings for all correct responses in this task. Significant main effects were observed for SPEAKER GROUP ($F(1,19) = 76.80$, $p < .001$, $r = .90$) and EMOTION ($F(4,76) = 14.98$, $p < .001$), and the two-way interaction of SPEAKER GROUP × EMOTION was statistically robust ($F(4,76) = 11.01$, $p < .001$). Post hoc tests indicated that emotional cues produced by the PD speakers, despite being correctly identified, were rated as less intense than those produced by healthy speakers for all of the emotions except *sadness*, where the mean ratings were virtually identical across speaker groups. The influence of disease (speaker) status on the perceived strength of vocal expressions of emotion is portrayed in Fig. 3B.

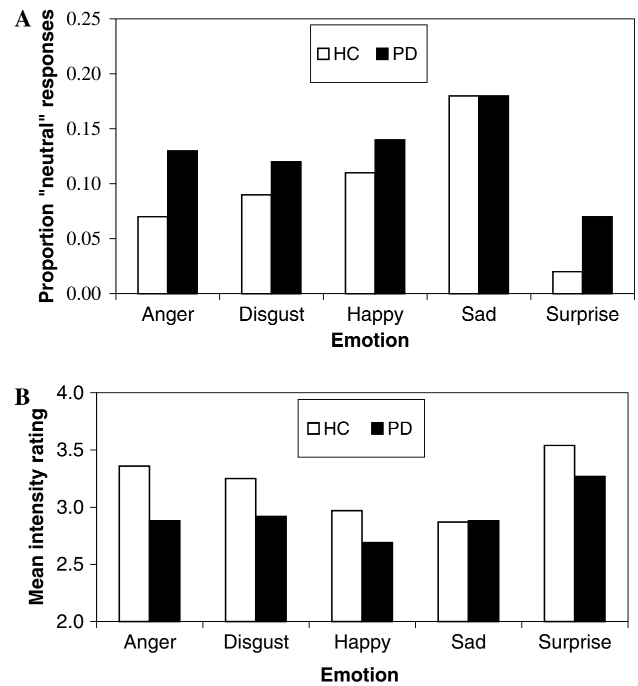

Fig. 3. Listeners' ability to detect emotional prosody when produced by speakers with Parkinson's disease (PD) and healthy control (HC) speakers, in reference to: (A) the proportion of errors to identify each of five emotions; and (B) the perceived intensity of these emotional expressions when they were identified correctly, on a 5-point scale of increasing intensity (range of 1–5).

3.5. *Influence of PD patient characteristics on listeners' judgements of prosody*

To shed light on individual performance characteristics in the PD speaker group briefly, the mean listener error proportions when judging prosody spoken by each of the 21 PD speakers in the four prosody conditions were examined overall (independent of task-specific variables). In reference to the "expected range" of listeners' scores in each condition (i.e., the HC group mean minus two standard deviations), there were few instances where individual PD speakers presented as prominent "outliers" on any of these tasks. In the Phonemic stress task, which was associated with a high degree of listener errors for both speaker groups, none of the PD speakers performed outside the HC group range. Two patients were "impaired" in the Contrastive stress (PD6, PD11) and Sentence mode (PD3, PD12) conditions and one patient was impaired for Emotional Prosody (PD12). Three of these four patients had predominantly left-sided motor signs and one had right-sided signs, and all four patients were two to four years post-diagnosis of PD (below the mean for the PD group). More importantly perhaps, all four patients had obtained UPDRS motor severity scores above the PD group mean and two of these individuals (PD11, PD12) were among the three patients most severely affected on this measure. The possibility that listeners' misperceptions of prosody were related overall to differences in age (years), education (years), PD motor disability (UPDRS motor score), cognitive status (Mattis Dementia Rating Scale total score), or depression (HDI score) in the PD group was examined by computing Pearson correlations between these background variables and an overall index of their prosody as judged by listeners (i.e., the mean listener errors collapsed across the four prosody tasks). There were no significant correlations observed from this analysis (p's > .05 in all cases).[2]

4. Discussion

Idiopathic Parkinson's disease is associated with significant difficulties in the ability to transmit meanings encoded by speech prosody in a communicatively adequate manner to listeners. This claim follows comprehensive evaluation of vocal-prosody expression in major linguistic and emotional contexts, where it was consistently noted that naive listeners experienced greater troubles in identifying the intended meanings when produced by adults with PD than by matched aging but still healthy speakers. These findings provide strong, empirical support for the idea that dysprosody in PD is a critical source of potential failures in intentional communication and in the social competence of those affected (McNamara & Durso, 2003; Pitcairn et al., 1990). Moreover, these data qualify certain aspects of prosodic communication that may be more susceptible to the effects of PD, furnishing more precise indications of how listeners perceive Parkinsonian speech in particular contexts.

4.1. Effects of dysprosody on linguistic-pragmatic communication

There were important signs that the ability to signal "stress" or "emphasis" to listeners—i.e., to use prosody to highlight the linguistic salience of key words or syllables in an utterance—was a pronounced area of weakness for PD speakers (Blonder et al., 1989; Darkins et al., 1988; Penner et al., 2001). Phonemic and contrastive stress refer to aspects of semantic and pragmatic structure, respectively, although stressed words in both contexts are cued by vowel elongation and increased f0 and amplitude variation which forms a local "pitch accent" in the speech stream (Cooper & Sorensen, 1981; Klatt, 1976; Pell, 2001). Here, listeners made significantly more errors to discriminate the intended meaning of these cues in lexical stress pairs (e.g., HOTdog vs. hot DOG) *and* to identify the sentence position of emphasized words produced by members of the PD group. These results, which were not influenced by linguistic variables of these tasks, suggest that prosodic cues necessary to detect stress were frequently inadequate when listening to the Parkinsonian speakers. This conclusion is further strengthened by the observation that contrastive stress tokens produced by the PD speakers were often perceived as lacking stressed words entirely on a more frequent basis than when listening to healthy adults.

One can argue that observed difficulties in how stress (particularly contrastive stress) was communicated to listeners by PD speakers were the consequence of critical reductions in acoustic contrast and detail long-attributed to Parkinsonian speech, which is known to display less variability in both fundamental frequency and intensity cues very early in the disease (Canter, 1963, 1965a; Harel et al., 2004; Kent & Rosenbek, 1982). Previous studies have described an acoustic "flattening" of pitch accents on words meant to bear lexical (Darkins et al., 1988) or contrastive (Penner et al., 2001) stress in PD speakers. These changes would mitigate the perceptual salience of local prosodic excursions for signalling both lexical and contrastive stress to listeners, promoting less distinctive and identifiable expressions of stress in the speech signal.

The ability of PD speakers to exploit prosody to convey the "mode" of an utterance as a statement or question was also deficient from the listeners' perspective, affecting how

[2] As suggested by an anonymous reviewer, the main ANOVAs on the identification errors were rerun for each of the four prosody tasks to understand how expected variability within each of our speaker groups would be reflected in significant main or interactive effects involving group when the 21 PD and 12 HC speakers were treated as randomly selected members of the respective populations (i.e., between-groups variable in the ANOVA). The proportion of identification errors made in reference to each speaker was computed as an average of the 20 listeners and the ANOVAs were rerun as described for the primary analyses. The main effect for Speaker Group was significant for the production of Contrastive stress (PD < HC, $F(1,31) = 8.29$, $p = .007$) but not for Phonemic stress or Sentence Mode (F's < 1.8, p's > .05). For Emotional Prosody identification errors, the main effect of Group was only significant for "anger" according to this analysis approach (PD < HC, $F(1,31) = 18.25$, $p = .0002$). In addition, a significant interaction of Speaker Group × Semantic Bias was observed for "anger" ($F(1,31) = 7.61$, $p < .01$) and "disgust" ($F(1,31) = 5.93$, $p = .02$); in both cases, post hoc analyses indicated that listeners committed more errors to identify anger and disgust from the PD rather than the HC group when there was no semantically biasing information in the stimulus (i.e., when prosody alone signalled these emotions). Finally, for emotional prosody intensity ratings, the two groups differed significantly in how listeners rated exemplars of "anger" ($F(1,31) = 5.83$, $p = .02$) and "surprise" ($F(1,31) = 4.04$, $p = .05$), which were rated as less intense for the PD speakers even when these expressions were correctly identified. These secondary analyses, while yielding fewer statistically reliable effects, reinforce that PD speakers were less successful at communicating both linguistic and emotional prosody to listeners, particularly in contexts for signalling contrastive stress and the emotion "anger."

well questions were recognized. Acoustic and perceptual data point to the paramount importance of terminal f0 parameters for differentiating sentence mode, with a marked rise for questions and a fall for statements (Lieberman, 1967; Majewski & Blasdell, 1968; Pell, 2001; Studdert-Kennedy & Hadding, 1973). Studies of PD have frequently described abnormalities in the production of terminal question rises by these patients (Blonder et al., 1989; Kegl et al., 1999; Le Dorze et al., 1992; Penner et al., 2001) but no difficulties in the production of statements (Blonder et al., 1989; Caekebeke et al., 1991; Penner et al., 2001; Scott et al., 1984). Data gathered here from the perspective of listeners are in full agreement with these earlier findings. If one accepts that natural forces of speech declination tend to produce a "falling" (statement) intonation contour with minimal interventions on the part of the speaker (Cohen, Collier, & 't Hart, 1982; Hauser & Fowler, 1992; Pierrehumbert, 1979), whereas production of the terminal (question) rise in pitch at the end of a breath unit is associated with increased physiological and articulatory efforts (i.e., vocal fold lengthening, Lieberman, 1967), one can speculate that the questioning mode is therefore more vulnerable to motor insufficiencies in many adults with PD. This possibility awaits further study to understand the source of our listeners' errors in the sentence mode task.

4.2. Effects of dysprosody on emotive communication

There has been little systematic evaluation of emotive communication in PD, nor is it known what impressions are routinely derived by listeners when PD patients communicate their emotions through prosody. The present data indicate that listeners experienced notable difficulties recognizing most emotional expressions produced by members of the PD group with the exception of *sadness*. There was especially strong evidence that expressions of *anger*, *disgust*, and *happiness* produced by the PD speakers were poorly representative of these emotions and frequently sounded "neutral" to listeners, lacking characteristic vocal inflections. These findings support previous data—which were based on highly limited speaker and/or listener samples—indicating that adults with PD are poor at signalling *anger* through prosody (Caekebeke et al., 1991; Penner et al., 2001; Scott et al., 1984), elaborating these findings to a broader set of emotions that appear to be problematic for many speakers with PD.

Expressions of *surprise* spoken by adults with PD were also impoverished according to listeners, who more frequently identified these as "neutral" when produced by PD compared to HC speakers. Data pertaining to *surprise* are interpreted with some caution, however, given the extremely brief, reactive nature of this emotion (Izard, 1977) which was likely difficult to simulate for many speakers in both groups, and which tends to be recognized from the voice less reliably than other emotions in traditional forced-choice perceptual tasks (Pell, 2002). Nonetheless, following closer inspection of these data, it bears mentioning that whereas listeners tended erroneously to identify many expressions of *surprise* as "neutral" for the PD speakers, they overwhelmingly identified *surprise* utterances as "happy" when they erred for the HC speakers. Thus, data on *surprise* re-assert the tendency for PD-produced utterances to sound relatively devoid of emotional details in the voice to many listeners, consistent with identification judgements of *happy* and *anger* expressions produced by the PD speakers. At the same time, these issues underscore that perceptual judgements based on *simulated* exemplars of emotion, which partially index skills related to the elicitation procedure, are likely to differ somewhat from those derived from spontaneous productions, which could be usefully examined in future research on prosody in PD.

The finding that *sad* expressions tended to be recognized by listeners with similar accuracy for both speaker groups was a unique finding among the five emotions studied here. In fact, based on the perceptual errors patterns recorded, there were indications that when the verbal content was further biased towards an interpretation of *sadness*, listeners recognized this emotion significantly better when the utterance had been produced by a member of the PD rather than the HC group. In addition, data on how *intensely* individuals with and without PD communicate their emotions revealed that listeners uniformly perceived vocal expressions of emotion as significantly less strong or intense when produced by Parkinsonian adults, with the sole exception of *sadness* where the mean intensity ratings for the two groups were practically identical. On the surface, these emotion-specific findings appear to substantiate reported impressions that many adults with PD to seem "unhappy," "cold," and less "likeable" than comparable peers without PD (Pitcairn et al., 1990).

Evidence that PD affects how these individuals convey several vocal emotions to others with the exception of *sadness* is probably governed by characteristic distinctions in the acoustic–perceptual attributes necessary to communicate these different emotions, some of which may be impacted to a lesser degree by motor limitations in PD. For example, if one considers those emotions which were most broadly affected from the perspective of listeners (i.e., *anger* and *happiness*), these emotions tend to be signalled by using a higher mean f0 and amplitude, with greater f0 and amplitude variation, than emotionally neutral utterances, and in particular, than *sad* utterances which are defined by a markedly low mean f0/pitch and relative absence of f0/intensity variation (Banse & Scherer, 1996; Juslin & Laukka, 2003; Pell, 2001; Williams & Stevens, 1972). Angry (and usually happy) sounding utterances also demonstrate an accelerated rate of delivery relative to sad utterances, which are characteristically slow in relative speaking rate (Juslin & Laukka, 2003; Williams & Stevens, 1972). In line with previous comments, motor restrictions on the speech apparatus which promote a lack of differentiation in the pitch *and* intensity parameters of Parkinsonian speech would impact most considerably on the identification of emotions such as *anger* or perhaps *happiness* which gain meaning through prominent, sustained long-term variations in the speech signal, as witnessed here. However, speech lacking in normal acoustic variation and with reduced energy might tend to facilitate reliable identification of *sadness* by listeners when speakers intended to express this emotion, given the convergence of Parkinsonian vocal characteristics with normal parameters for expressing and understanding *sadness* in humans.

It is interesting to note that the effects of psychomotor retardation on the voice of patients with major depression are defined by similar reductions in stress, pitch, and intensity variation in speech (Darby, Simmons, & Berger, 1984; Kuny & Stassen, 1993) which are sometimes indistinguishable from those witnessed in speech produced by adults with idiopathic PD (Flint, Black, Campbell-Taylor, Gailey, & Levinton, 1993). In terms of how these vocal features affect listeners, the present findings imply that Parkinsonian speakers are often perceived as "sad," "depressed," or mildly negative in valence, a pattern which may lead to frequent misattributions of how speakers with PD are truly feeling or responding to situations in their daily lives.

4.3. The impact of Parkinson's disease on communication

The current findings emphasize ways in which linguistic and emotional communication through prosody is deficient in PD, highlighting that these communicative failures are likely to present as an important social barrier for those affected by the disease. It is interesting to note that while all of the patients studied were rated as highly intelligible, the negative effects of dysprosody on successful vocal communication was already detectable to listeners for the PD group assessed. Thus, one can conclude that dysprosody in PD likely contributes to reductions in speech intelligibility in many patients (Kempler & Van Lancker, 2002), perhaps increasingly as the severity of motor disturbance advances in the disease; this relationship could be usefully tested by comparing a set array of speech parameters produced by patients in the mild and more advanced stages of PD, or through longitudinal re-examination of a PD speaker sample at progressive intervals in the disease. Nonetheless, independent of any association between impressions of dysprosody and speech intelligibility, the present data point out that limited control of the vocal apparatus in PD has serious and perhaps *earlier* (Harel et al., 2004) repercussions on how patients communicate direct intentions in their speech that are encoded at the level of prosody, pending further work in this investigative area.[3]

In each of the tasks administered, it merits emphasizing that very few individuals in the PD group were impaired disproportionately over other members of the group (with the possible exception of PD12 on two tasks). By the same token, results of our secondary analyses which treated the speakers with and without PD, rather than the listeners, as the independent grouping variable imply that the ability to communicate contrastive stress, *anger*, and *disgust* to listeners are likely most problematic for the largest number of PD speakers based on our combined analysis approaches. These prosodic difficulties were witnessed in the presence of optimal medication in the PD individuals evaluated, and did not bear a meaningful relationship to general differences in motor severity in the mild to moderate range, to depressive signs, cognitive status, or other key demographic variables. These observations suggest that reduced efficacy in the area of prosodic communication is both a gradual and widespread feature of PD that is *directly* linked to nigrostriatal degeneration of motor pathways in the disease (Canter, 1965b; Darley et al., 1975), rather than to changes in cognition, executive functions, or mood that appear to contribute to other forms of communicative impairments sometimes associated with the disease.

Indeed, there is growing awareness that interruptions within the basal ganglia and frontal–striatal pathways in PD can yield a range of difficulties that affect language, communication, and interpersonal skills in both the expressive *and* receptive modalities (Berg, Bjornram, Hartelius, Laakso, & Johnels, 2003; Friederici, Kotz, Werheid, Hein, & von Cramon, 2003; Grossman et al., 2002; Pell & Leonard, 2005). In addition to difficulties expressing prosody in an adequate manner, non-demented adults with PD frequently present with reduced sensitivity to prosodic meanings during speech comprehension tasks (Blonder et al., 1989; Breitenstein, Van Lancker, Daum, & Waters, 2001; Lloyd, 1999; Pell, 1996). In a recent investigation (Pell & Leonard, 2003), the receptive abilities of the 21 PD patients evaluated here were assessed and this group of individuals was characterized by significant impairments in the identification of emotional prosody. Thus, comparative analysis of prosodic abilities in a sufficiently large and unitary sample of PD participants suggests that one might expect both production and comprehension difficulties for prosody in the early course of idiopathic PD, although the source of these expressive and receptive impairments may well be distinct (Pell & Leonard, 2003). Future research on Parkinson's disease will be well served to consider the nature of both expressive and receptive failures in communication if interventions suitable to this clinical population are to be devised and implemented.

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[3] The possibility that changes in breath groups contributed to our results was briefly considered post hoc by having the first two authors listen to the utterances produced by the four PD patients who were deemed "impaired" in our different prosody tasks. There were no audible differences in the breath groups produced by these patients, and as one might expect when producing short sentences, all speakers uniformly produced each token in a single breath implying that this was not a major factor in the perceptual findings.

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References

Banse, R., & Scherer, K. R. (1996). Acoustic profiles in vocal emotion expression. *Journal of Personality and Social Psychology, 70*(3), 614–636.

Benke, T., Bosch, S., & Andree, B. (1998). A study of emotional processing in Parkinson's disease. *Brain and Cognition, 38*(1), 36–52.

Berg, E., Bjornram, C., Hartelius, L., Laakso, K., & Johnels, B. (2003). High-level language difficulties in Parkinson's disease. *Clinical Linguistics and Phonetics, 17*(1), 63–80.

Blonder, L. X., Gur, R. E., & Gur, R. C. (1989). The effects of right and left hemiparkinsonism on prosody. *Brain and Language, 36*, 193–207.

Breitenstein, C., Van Lancker, D., Daum, I., & Waters, C. (2001). Impaired perception of vocal emotions in Parkinson's disease: Influence of speech time processing and executive functioning. *Brain and Cognition, 45*, 277–314.

Caekebeke, J. F. V., Jennekens-Schinkel, A., van der Linden, M. E., Buruma, O. J. S., & Roos, R. A. C. (1991). The interpretation of dysprosody in patients with Parkinson's disease. *Journal of Neurology, Neurosurgery, and Psychiatry, 54*, 145–148.

Calne, D., Snow, B., & Lee, C. (1992). Criteria for diagnosing Parkinson's disease. *Annals of Neurology, 32*, S125–S127.

Canter, G. J. (1963). Speech characteristics of patients with Parkinson's disease: I. Intensity, pitch, and duration. *Journal of Speech and Hearing Disorders, 28*(3), 221–229.

Canter, G. J. (1965a). Speech characteristics of patients with Parkinson's disease: II. Physiological support for speech. *Journal of Speech and Hearing Disorders, 30*, 44–49.

Canter, G. J. (1965b). Speech characteristics of patients with Parkinson's disease: III. Articulation, diadochokinesis, and over-all speech adequacy. *Journal of Speech and Hearing Disorders, 30*, 217–224.

Cheang, H. S., & Pell, M. D. (2004). The effects of Parkinson's disease on the production of contrastive stress. *Journal of the Acoustical Society of America, 115*(5/2), 2424.

Cohen, A., Collier, R., & 't Hart, J. (1982). Declination: Construct or intrinsic feature of speech pitch? *Phonetica, 39*, 254–273.

Cooper, W., & Sorensen, J. (1981). *Fundamental frequency in sentence production*. New York: Springer.

Critchley, E. M. R. (1981). Speech disorders of Parkinsonism: A review. *Journal of Neurology, Neurosurgery, and Psychiatry, 44*, 751–758.

Cummings, J., Darkins, A., Mendez, M., Hill, M., & Benson, D. F. (1988). Alzheimer's disease and Parkinson's disease: Comparison of speech and language alterations. *Neurology, 38*, 680–684.

Darby, J. K., Simmons, N., & Berger, P. (1984). Speech and voice parameters of depression: A pilot study. *Journal of Communication Disorders, 17*, 75–85.

Darkins, A. W., Fromkin, V. A., & Benson, D. F. (1988). A characterization of the prosodic loss in Parkinson's Disease. *Brain and Language, 34*, 315–327.

Darley, F., Aronson, A., & Brown, J. (1975). *Motor speech disorders*. Philadelphia: Saunders.

De Bodt, M., Hernandez-Diaz Huici, M., & Van de Heyning, P. (2002). Intelligibility as a linear combination of dimensions in dysarthric speech. *Journal of Communication Disorders, 35*, 283–292.

Flint, A. J., Black, S., Campbell-Taylor, I., Gailey, G., & Levinton, C. (1993). Abnormal speech articulation, psychomotor retardation, and subcortical dysfunction in major depression. *Journal of Psychiatry Research, 27*(3), 309–319.

Friederici, A. D., Kotz, S. A., Werheid, K., Hein, G., & von Cramon, D. Y. (2003). Syntactic comprehension in Parkinson's disease: Investigating early automatic and late integrational processes using event-related brain potentials. *Neuropsychology, 17*(1), 133–142.

Grossman, M., Zurif, E., Lee, C., Prather, P., Kalmanson, J., Stern, M., et al. (2002). Information processing speech and sentence comprehension in Parkinson's disease. *Neuropsychology, 16*(2), 174–181.

Harel, B., Cannizzaro, M., Cohen, H., Reilly, N., & Snyder, P. (2004). Acoustic characteristics of Parkinsonian speech: A potential biomarker of early disease progression and treatment. *Journal of Neurolinguistics, 17*, 439–453.

Hauser, M. D., & Fowler, C. A. (1992). Fundamental frequency declination is not unique to human speech: Evidence from nonhuman primates. *Journal of the Acoustical Society of America, 91*(1), 363–369.

Illes, J. (1989). Neurolinguistic features of spontaneous language production dissociate three forms of neurodegenerative disease: Alzheimer's, Huntington's, Parkinson's. *Brain and Language, 37*, 628–642.

Izard, C. E. (1977). *Human emotions*. New York: Plenum Press.

Juslin, P., & Laukka, P. (2003). Communication of emotions in vocal expression and music performance: Different channels, same code? *Psychological Bulletin, 129*(5), 770–814.

Kegl, J., Cohen, H., & Poizner, H. (1999). Articulatory consequences of Parkinson's Disease: Perspectives from two modalities. *Brain and Cognition, 40*, 355–386.

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

Kent, R. D., & Rosenbek, J. C. (1982). Prosodic disturbance and neurologic lesion. *Brain and Language, 15*, 259–291.

Klatt, D. H. (1976). Linguistic uses of segmental duration in English: Acoustic and perceptual evidence. *Journal of the Acoustical Society of America, 59*(5), 1208–1221.

Kuny, S., & Stassen, H. H. (1993). Speaking behavior and voice sound characteristics in depressive patients during recovery. *Journal of Psychiatry Research, 27*(3), 289–307.

Le Dorze, G., Dionne, L., Ryalls, J., Julien, M., & Ouellet, L. (1992). The effects of speech and language therapy for a case of dysarthria associated with Parkinson's disease. *European Journal of Disorders of Communication, 27*, 313–324.

Lieberman, P. (1967). *Intonation, perception, and language*. Cambridge, MA: MIT Press.

Lloyd, A. J. (1999). Comprehension of prosody in Parkinson's disease. *Cortex, 35*, 389–402.

Majewski, W., & Blasdell, R. (1968). Influence of fundamental frequency cues on the perception of some synthetic intonation contours. *Journal of the Acoustical Society of America, 45*(2), 450–457.

McNamara, P., & Durso, R. (2003). Pragmatic communication skills in patients with Parkinson's disease. *Brain and Language, 84*, 414–423.

Pell, M. D. (1996). On the receptive prosodic loss in Parkinson's disease. *Cortex, 32*(4), 693–704.

Pell, M. D. (2001). Influence of emotion and focus location on prosody in matched statements and questions. *Journal of the Acoustical Society of America, 109*(4), 1668–1680.

Pell, M. D. (2002). Evaluation of nonverbal emotion in face and voice: Some preliminary findings on a new battery of tests. *Brain and Cognition, 48*, 499–504.

Pell, M. D., & Leonard, C. L. (2003). Processing emotional tone from speech in Parkinson's disease: A role for the basal ganglia. *Cognitive, Affective and Behavioral Neuroscience, 3*(4), 275–288.

Pell, M. D., & Leonard, C. L. (2005). Facial expression decoding in early Parkinson's disease. *Cognitive Brain Research, 23*, 327–340.

Penner, H., Miller, N., Hertrich, I., Ackermann, H., & Schumm, F. (2001). Dysprosody in Parkinson's disease: An investigation of intonation patterns. *Clinical Linguistics and Phonetics, 15*(7), 551–566.

Pierrehumbert, J. (1979). The perception of fundamental frequency declination. *Journal of the Acoustical Society of America, 66*(2), 363–369.

Pitcairn, T. K., Clemie, S., Gray, J. M., & Pentland, B. (1990). Impressions of parkinsonian patients from their recorded voices. *British Journal of Disorders of Communication, 25*(1), 85–92.

Rosenthal, R. (1991). Meta-analytic procedures for social research. *Applied Social Research Methods, 6*, 19.

Scott, S., Caird, F., & Williams, B. (1984). Evidence for an apparent sensory speech disorder in Parkinson's disease. *Journal of Neurology, Neurosurgery, and Psychiatry, 47*, 840–843.

Studdert-Kennedy, M., & Hadding, K. (1973). Auditory and linguistic processes in the perception of intonation contours. *Language and Speech, 16*, 293–313.

Williams, C. E., & Stevens, K. N. (1972). Emotions and speech: Some acoustical correlates. *The Journal of the Acoustical Society of America, 52*(4(2)), 1238–1250.