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Understanding speaker attitudes from prosody by adults with Parkinson's disease

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The ability to interpret vocal (prosodic) cues during social interactions can be disrupted by Parkinson's disease, with notable effects on how emotions are understood from speech. This study investigated whether PD patients who have emotional prosody deficits exhibit further difficulties decoding the attitude of a speaker from prosody. Vocally inflected but semantically nonsensical 'pseudo-utterances' were presented to listener groups with and without PD in two separate rating tasks. Task 1 required participants to rate how confident a speaker sounded from their voice and Task 2 required listeners to rate how polite the speaker sounded for a comparable set of pseudo-utterances. The results showed that PD patients were significantly less able than HC participants to use prosodic cues to differentiate intended levels of speaker confidence in speech, although the patients could accurately detect the polite/impolite attitude of the speaker from prosody in most cases. Our data suggest that many PD patients fail to use vocal cues to effectively infer a speaker's emotions as well as certain attitudes in speech such as confidence, consistent with the idea that the basal ganglia play a role in the meaningful processing of prosodic sequences in spoken language (Pell & Leonard, 2003).

Humans typically use verbal and non-verbal signals in tandem to convey information about their mental and affective state to listeners (DePaulo & Friedman 1998). Even in the absence of verbal content, listeners can often decipher a speaker's affective states, feelings and attitude towards the listener (e.g. expressing sarcasm or approval) by strictly attending to non-verbal indicators such as facial expressions or vocal cues, or speech prosody (Wichmann, 2000). In the vocal channel, sensitivity to prosodic variations over the course of an utterance appears to be essential for interpreting vocal expressions of emotion and certain attitudes in speech (Pell, 2007).

Two recurring instances in which listeners must harness prosodic cues to infer the intended attitude of the speaker are to determine the relative confidence of a speaker in what they are saying (confident/doubtful) and the relative politeness of the speaker

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towards the listener (polite/impolite). The manner in which prosodic cues communicate each of these attitudes has been investigated in healthy adults to some degree. Prosodic cues of speaker confidence, which convey critical information about the probable 'truth-value' of a verbal message, include combined alterations in loudness, pitch and temporal characteristics of an utterance. Specifically, relatively 'high' speaker confidence tends to be expressed with short and infrequent pauses, increases in loudness and speaking rate, and terminal falls in intonation contours (Barr, 2003; Kimble & Seidel, 1991). The expression of 'low' speaker confidence (doubt) generally corresponds with pre-speech delays and the production of rising intonation contours and/or elevated pitch (Boltz, 2005; Brennan & Williams, 1995). Similarly, politeness is cued by modulations of various acoustic parameters (Trees & Manusov, 1998). Polite utterances tend to be produced with a relatively high or rising voice pitch, whereas utterances spoken with a low or falling pitch contour are perceived as less polite (Brown & Levinson, 1987; Loveday, 1981). Decreased loudness while speaking may also signal greater politeness by reducing the imposition of the verbal message on the listeners' auditory space (Culpeper, Bousfield, & Wichmann, 2003).

Despite the central role of prosody for communicating many speaker attitudes, the effects of brain damage on these skills have not been widely evaluated, in contrast to a growing literature on how brain-damaged patients process emotions from prosody. Recently, Pell (2006, 2007) found that adults with right hemisphere cortical lesions were impaired in the comprehension of vocal emotions from prosody, as well as certain attitudes such as confidence and politeness, when compared with a healthy control group. These results were interpreted as further indication that the right hemisphere serves a major role in the decoding of various emotive qualities of speech prosody. The data further highlighted that difficulties to process emotions and attitudes may sometimes coexist in certain brain-damaged populations whose prosodic abilities are negatively affected.

Prosody is also known to be disturbed in individuals with basal ganglia dysfunction due to focal subcortical lesions (Cancelliere & Kertesz, 1990; Starkstein, Federoff, Price, Leiguarda, & Robinson, 1994; Weddell, 1994), Huntington's disease (Speedie, Brake, Folstein, Bowers, & Heilman, 1990) or Parkinson's disease (Blonder, Gur, & Gur, 1989; Kan, Kawamura, Hasegawa, Mochizuki, & Nakamura, 2002; Pell, 1996). Using Parkinson's disease (PD) as a model of impaired basal ganglia functioning, Pell and Leonard examined the emotional processing abilities of non-demented PD patients in reference to healthy adults in a variety of stimulus- and task-dependent conditions. They reported that PD patients were impaired in the use of prosodic but not facial cues to identify emotion, and that these prosodic deficits were not fully predicted by changes in mood, memory or executive functions. In light of the wider literature, it was suggested that the PD patients exhibited prosody comprehension deficits because the basal ganglia (striatum) assume a critical supporting role in the processing of vocal cue sequences in speech (see Pell and Leonard, 2003, 2005, for a detailed account). Other researchers have implicated the basal ganglia in tasks of speech sequencing as well (Meyer, Steinhauer, Alter, Friederici, & von Cramon, 2004).

While the ability to decode speaker attitudes from prosody in PD is unknown, one can predict that neuropsychological deficits at the level of prosody, which affect the processing of vocal emotions in speech, could determine how well PD patients understand speaker attitudes from prosody, limiting their functional communication skills in a negative manner. The goal of this investigation was to initiate research on how PD patients decode speaker attitudes from prosody through continued evaluation of a PD sample with documented impairments for recognizing emotional prosody (Dara, Monetta, & Pell, 2008). As reported in that companion study that focused on emotional processing abilities in different communication channels (involving face, voice and/or language content), a group of 16 non-demented adults with PD failed to normally recognize emotional meanings when presented in semantically meaningless 'pseudo-utterances' that contained only prosodic cues (e.g. *The fector egzullin tuh boshent*). However, the PD patients could identify the emotional meaning of utterances from verbal-semantic cues (e.g. for anger: *You burnt me with your cigarette!*) and from facial expressions. This pattern implies that difficulties in the PD group centred on the use of prosodic information for understanding emotions in speech. In the current study, we tested the same participants to determine whether the PD patients can decode attitudinal information when listening to pseudo-utterances devoid of semantic content but with clear attitudinal meaning at the level of prosody. We predicted that the PD participants would display a reduced appreciation of speaker attitudes compared to healthy adults when forced to rely on prosodic cues, as part of a broader deficit for processing long-term prosodic variations in speech (Meyer *et al.*, 2004; Pell & Leonard, 2003).

Method

Participants

Participants were 16 adults diagnosed with idiopathic PD and 17 matched healthy control (HC) participants who had taken part in a previous study of emotional prosody (Dara *et al.*, 2008). All participants were native speakers of Canadian English residing in the city of Montréal (Québec). Individuals in each group were comparable in age (PD: *Mean* = 66.0, *SD* = 9.0; HC: *Mean* = 66.9, *SD* = 9.3) and years of education (PD: *Mean* = 14.8, *SD* = 2.9; HC: *Mean* = 15.5, *SD* = 2.5). Diagnosis of idiopathic PD was confirmed by a neurologist on the basis of accepted motor criteria (e.g. Calne, Snow, & Lee, 1992). Disease duration within the PD group (post-diagnosis) was an average of 8.2 years (*SD* = 3.6). Motor disability of individuals within the PD group was in the mild-to-moderate severity range according to Hoehn and Yahr (1967) staging criteria (stages I–IV, *Mean* = 3.0, *SD* = 0.9). All patients were medicated during testing as follows: levodopa-carbidopa (*N* = 10), dopamine agonists/Mirapex (*N* = 5), monoamine oxidase-B inhibitor/Selegiline (*N* = 3), catechol-O-methyltransferase inhibitor (*N* = 3), amantadine (*N* = 6) and Permax (*N* = 4). Three PD patients were receiving an antidepressant. None of the patients had a history of substance abuse, major medical or neurological difficulties other than PD, or had undergone brain surgery.

Individuals in both groups were screened for dementia prior to the experiment using the Mattis Dementia Rating Scale (Mattis, 1988); no participants fit the criteria for dementia and there were no group differences in general mental status, $t(31) = -0.76$, $p = .4$. The presence and severity of depression in all PD and HC participants were estimated with the Hamilton Depression Inventory (HDI–SF). One PD participant satisfied the criteria for severe depression (HDI–SF score = 21.5), one patient was moderate (score = 14.0) and one patient was mild (score = 10.5). All participants had normal or corrected-to-normal vision as well as acceptable hearing thresholds at frequencies important to speech intelligibility, following pure tone audiometric screening (minimum 30 dB HL in each ear at 500, 1,000 and 2,000 Hz).

Prior to testing, each PD and HC participant was evaluated using standardized neuropsychological tests (e.g. to probe cognitive processes such as memory and attention) and typical tests of 'frontal lobe functioning' (e.g. mental set-switching, planning, problem-solving or inhibiting irrelevant information). The scores of tests administered and the results of *t tests* comparing both groups of participants are summarized in Table 1, together with the results of emotional processing tasks presented by Dara *et al.* (2008) in which the same participants identified emotions from verbal descriptions, static faces and emotional prosody in utterances with and without congruent semantic information. It can be seen that, in addition to selective difficulties in the processing of emotional prosody, a reduction in verbal working memory capacity in the PD group (listening span task) represented the most pronounced difference between the two groups.

Table 1. Major neuropsychological features of the healthy control (HC) participants and individuals with Parkinson's disease (PD)

	PD ($N = 16$)		HC ($N = 17$)		
Variable (units)	*M*	*SD*	*M*	*SD*	*t test*
Mattis Dementia Rating Scale (/144)	137.8	5.0	139.1	4.4	NS
Identify emotions from verbal scenarios (%)*	74.0	16.0	79.0	16.0	NS
Identify emotions from static faces (%)*	81.3	21.3	87.3	15.3	NS
Identify emotions from prosody + semantics (%)*	80.9	16.5	82.9	17.6	NS
Identify emotions from prosody alone (emotional pseudo-utterances) (%)*	55.5	23.1	63.6	24.3	$p < .05$
Auditory Digit Span, forward (/9)	6.8	0.9	7.2	1.6	NS
Verbal working memory/listening span (words recalled, /42)	28.2	5.1	35.5	5.2	$p < .001$
Tower of London (initiation time)	109.8	17.9	117.5	17.6	NS
Verbal fluency task: animals (number/minute)	15.5	4.7	21.2	10.0	NS
Colour Trail Making Test B (seconds to complete)	115.7	52.4	93.4	23.8	NS
Warrington recognition memory: words	45.6	5.6	48.4	1.8	NS
Benton phoneme discrimination (/30)	27.3	1.9	27.7	1.5	NS
Benton face recognition (/54)	41.9	5.4	47.6	3.9	$p < .05$

*Initially reported by Dara *et al.* (2008). *M*, Mean; *SD*, Standard deviation; *NS*, Non-significant; $p > .05$. Significant group differences always reflect poorer performance by the PD compared to the HC group.

Experimental tasks and materials

Each participant completed two rating tasks that tested the ability to infer speaker confidence (Task 1) and speaker politeness (Task 2) from pseudo-utterances devoid of meaningful verbal content. The sentences employed in each task were uniquely constructed for the purposes of testing each speaker's attitude as summarized in each section below (see Pell, 2007 for complete details on the stimulus validation procedure conducted for each task). All stimuli were recorded with a high-quality microphone on to digital audiotape (sampling rate: 24 kHz, 16 bit, mono) and then edited for experimental presentation using Praat speech analysis software (Boersma & Weenink, 2005).

Task 1: Speaker confidence rating

The confidence stimuli were pseudo-utterances (e.g. '*You rint mig at the flugs*') produced in the form of a declarative statement by four male speakers of Canadian

English who shared the same dialect as the experimental participants. The structure of the pseudo-utterances mimicked natural sentences, which might be spoken in response to a request for directions (e.g. *You turn left at the lights*) or a clarification about the location of an object, in which speakers would use prosody to express different levels of confidence in their knowledge. Each sentence was 6–11 syllables in length and was produced by the speakers to project each of three distinct levels of confidence: high, moderate and low (doubt). A pilot study was run in which ten native English speakers from Montréal (five male and five female students at McGill University) rated the perceived confidence of each sentence on a five-point continuous scale. The 15 items that best exemplified each level of speaker confidence (high, moderate and low) based on the mean ratings for the pilot group[1] were selected for the experiment (3 confidence levels × 15 tokens = 45 stimuli total). In addition to being perceptually distinct, items representing each confidence level were acoustically distinct with respect to mean fundamental frequency (f0) ($F(2, 42) = 4.38$, $p = .02$), f0 range ($F(2, 42) = 5.4$, $p < .01$) and speech rate ($F(2, 42) = 11.38$, $p < .001$) as shown in Table 2. Tokens spoken with high confidence were associated with a lower mean fundamental frequency than low confidence items, and both high and moderate confidence utterances displayed a reduced f0 range than utterances rated as low in confidence. High confidence tokens were also faster in speaking rate than both moderate and low confidence tokens.

Table 2. Basic acoustic measures of the stimuli presented in the confidence and politeness rating tasks. All measures of the confidence stimuli were averaged for four male speakers, whereas all measures of the politeness stimuli were averaged for two female speakers

	Acoustic parameter		
Task/stimulus features	Mean f0 (Hz)	f0 range (Hz)*	Speech rate (syllables/s)
Confidence level			
High	116	62	4.46
Moderate	127	56	4.30
Low	136	103	3.18
Politeness level			
High	268	254	4.05
Low	226	175	3.81

*Computed as the maximum minus the minimum f0 value for each utterance.

Task 2: Speaker politeness rating

The politeness stimuli were comparable pseudo-utterances produced by two female speakers of Canadian English. The speakers used prosody to produce each pseudo-utterance as if they were issuing a (polite) request to the listener to perform an action, such as to 'wash the dishes' or issuing a (relatively impolite) command to perform the action. Thus, prosody signalled two levels of politeness for each item: 'high' and 'low'. To allow for variations in utterance length, each speaker produced 'short' (*Gub the*

[1] *The perceptual ratings obtained from the confidence validation study, in reference to a five-point scale of increasing confidence, were as follows: 'high confidence' utterances had ratings that ranged between 4.33 and 5.00 (SD ≤ 0.83), those for 'moderate confidence' utterances ranged between 2.7 and 3.6 (SD ≤ 0.94) and 'low confidence' utterances received ratings between 1.11 and 1.78 (SD ≤ 0.97).*

mooshes) and 'long' ('*Voriful yoza gub the mooshes*') pseudo-utterances to signal each level of politeness. As with the confidence stimuli, a pilot study involving eight English-speaking undergraduate students (five females and three males) was conducted to ensure that tokens that best exemplified each politeness level were chosen for the experiment. Each pilot participant listened to the full set of recorded pseudo-utterances ($N = 64$) and rated the perceived politeness of the speaker using a five-point politeness scale. Based on the mean ratings of the pilot group[2], 32 perceptually distinct stimuli were chosen for the experiment (two politeness levels x eight items x two utterance lengths). Acoustic analyses indicated that high and low politeness utterances differed in mean fundamental frequency, $F(1, 14) = 12.79, p < .01$, and f0 range, $F(1, 14) = 4.64$, $p < .05$, but not speaking rate. As shown in Table 2, pseudo-utterances associated with high politeness were spoken with a higher mean f0 and greater f0 variation (range) than items rated as low in politeness irrespective of utterance length. Since we observed no main or interactive effects of sentence length on our acoustic measures, and our previous study revealed no effect of utterance length on politeness judgements using the same stimuli (Pell, 2007), short and long pseudo-utterances within each politeness category were considered comparable for this experiment and not entered as a separate factor in the analyses of the politeness task.

General procedure

Neuropsychological testing of each participant was completed during two one-hour sessions, followed by the two tasks of speaker attitude rating which were administered during a third session lasting 45 minutes. PD patients were tested at their home at a time of day shortly after taking their medication ('on-state'), whereas HC participants were tested in a quiet laboratory environment at McGill University. Subjects were paid a nominal fee (CAD $10/hr) at the end of testing.

Prosody rating tasks were run using Superlab Pro 2.0 software (Cedrus, USA) and participant responses were recorded on a Cedrus 7-button (730) response box. Participants were seated in a comfortable chair approximately 60 cm from the computer screen. Each task began with detailed instructions and a practice session followed by two experimental blocks of 22 or 23 randomized trials for the confidence task, and one experimental block of 32 randomized trials for the politeness task. The order for presenting the confidence vs. the politeness rating task was alternated within groups. Participants listened to each sentence only once and then rated the perceived confidence (Task 1) or politeness (Task 2) of the speaker along a five-point Likert scale, which was simultaneously displayed on the computer screen. The scale ranged from 1 ('not at all' confident or polite, depending on the task) to 5 ('very much' confident or polite). Participants were informed that the sentences were not supposed to 'make sense', but that they should listen closely to the utterance to judge how confident or polite speakers sounded in their speech. No time limitations were imposed on responses and the numerical rating assigned to each item served as the dependent measure for subsequent analyses.

[2] *The perceptual ratings obtained from the politeness validation study, in reference to a five-point scale of increasing politeness, were as follows: 'high politeness' utterances had ratings of 4.23 ($SD \leq 0.77$) and 'low politeness' utterances had ratings of 1.44 ($SD \leq 0.55$).*

Results

The mean confidence (Task 1) and politeness (Task 2) ratings assigned by participants in each group are furnished in Table 3. For each attitude, data analysis examined both the mean ratings assigned to each attitude level and the frequency distribution responses assigned by listeners with and without PD in each stimulus condition. Performance on the attitude rating tasks was then compared with measures of emotional prosody comprehension and key neuropsychological background measures of the PD group to establish a broader context for our data.

Table 3. Mean ratings assigned by healthy control (HC) listeners and listeners with Parkinson's disease (PD) in the confidence and politeness rating tasks. A rating of '5' signifies that the target attitude was 'very much' present, whereas a rating of '1' signifies that the attitude was 'not at all' present. Standard deviations are provided in the parentheses

	Participant group	
Task/stimulus features	PD ($N = 16$)	HC ($N = 17$)
Confidence rating		
High	3.93 (0.60)	4.11 (0.50)
Moderate	2.85 (0.50)	3.05 (0.60)
Low	1.62 (0.40)	1.46 (0.30)
Politeness rating		
High	3.90 (0.57)	3.90 (0.60)
Low	2.15 (0.47)	1.90 (0.39)

Task 1: Speaker confidence rating

For speaker confidence, a 2×3 ANOVA considered the impact of GROUP (PD, HC) on the mean ratings assigned to utterances spoken at different levels of CONFIDENCE (high, moderate or low). As expected, the mean ratings were significantly influenced by the pre-determined confidence level, $F(2, 62) = 237.56$, $p = .00001$. *Post hoc* inspection of the main effect (Tukey's HSD test, $p < .05$) showed that vocal cues signifying a high degree of confidence yielded higher ratings than those conveying moderate confidence, which in turn obtained higher ratings than utterances spoken with low confidence (doubt). This pattern of responses was not affected by Group status in the form of a main or interactive effect (both F values < 1.51, p values $> .23$).

Following Pell (2007), performance in this condition was examined further by considering the frequency of responses assigned at each interval of the confidence politeness scale when participants in each group listened to utterances expressing high, moderate or low confidence. Chi-squared analyses indicated that the distribution of responses assigned by the PD patients was independent from that assigned by the HC group when judging tokens that exemplified high ($\chi^2(4) = 10.05$, $p < .05$), moderate ($\chi^2(4) = 13.42, p < .01$) and low ($\chi^2(4) = 18.39, p < .01$) levels of speaker confidence. As suggested by Figure 1, there appeared to be qualitative differences in how PD patients differentiated stimuli representing the three confidence levels, particularly for those stimuli perceived by HC listeners as very 'high' or 'low' in confidence (i.e. intervals '5' and '1–2' on the rating scale). A Chi-squared analysis that compared the overall sensitivity of each group for judging speaker confidence, summed across the three confidence categories (involving 765 responses from HC listeners and 720

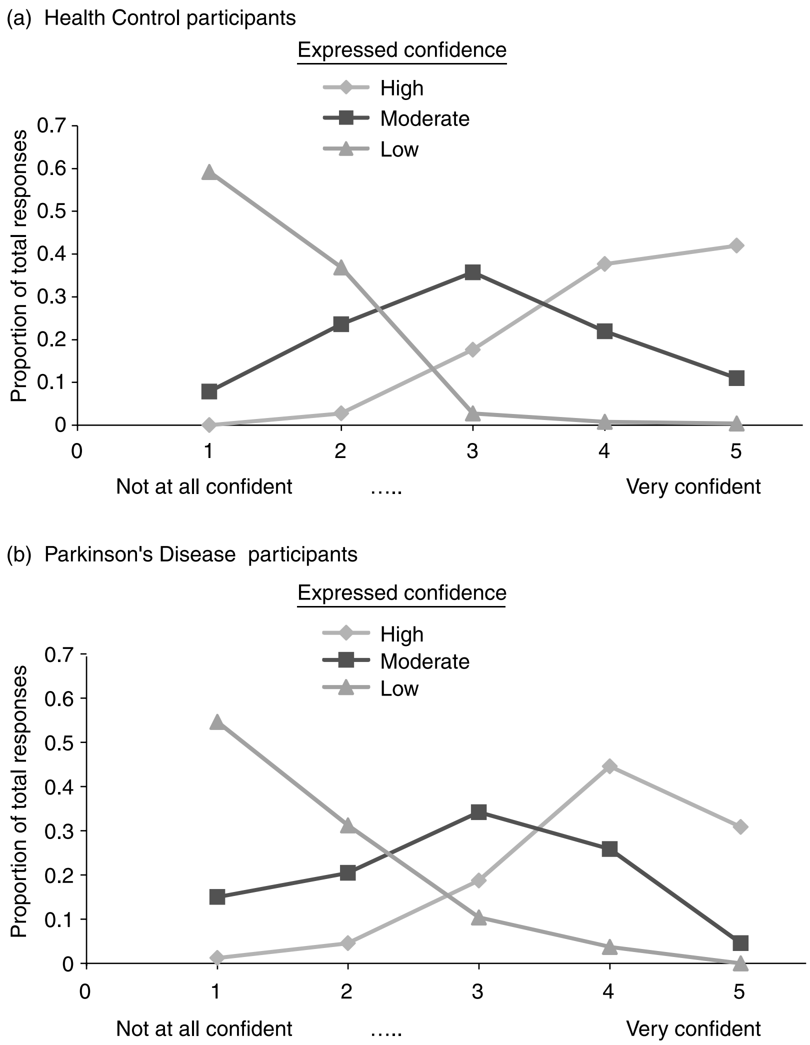

Figure 1. Sensitivity of healthy control (HC) listeners and listeners with Parkinson's disease (PD) to three levels of speaker confidence (high, moderate, low) according to the relative frequency of ratings assigned at each interval of a five-point scale.

responses from PD listeners), indicated that the frequency distributions of the two groups were statistically independent when rating confidence overall ($\chi^2(4) = 14.71$, $p < .01$).

Task 2: Speaker politeness rating

For speaker politeness, a 2 × 2 ANOVA considered the impact of GROUP (PD, HC) on the mean ratings assigned to utterances spoken at different levels of POLITENESS (high and low). Overall, the mean ratings were influenced as a main effect of the intended politeness level of the stimuli, $F(1, 31) = 220.41$, $p < .0001$. *Post hoc* comparisons (using Tukey's HSD) indicated that sentences exhibiting a high/rising pitch were always judged as more polite than those spoken in a low/falling intonation. There was no main or interactive effect of group on this pattern (both *F* values < 1.47, *p* values $> .23$).

As before, chi-squared analyses considered whether the frequency distribution of responses assigned by the PD and the HC groups were statistically independent when judging utterances for which prosody conveyed a 'high' or 'low' level of politeness. Results indicated that the PD patients did not respond in the same manner as the HC group when rating utterances expressing 'low' politeness (i.e. impoliteness) ($\chi^2(4) = 13.08$, $p = .02$), although the two groups demonstrated similar response distributions when judging utterances that conveyed high politeness ($\chi^2(4) = 9.37$, $p \leq 0.1$) (see Figure 2). A chi-squared analysis that compared the group rating distributions summed across the two politeness categories (involving 578 responses from HC and 544 responses from PD) revealed no evidence of group differences in the politeness condition overall ($\chi^2(4) = 4.53$, $p \leq 0.1$).

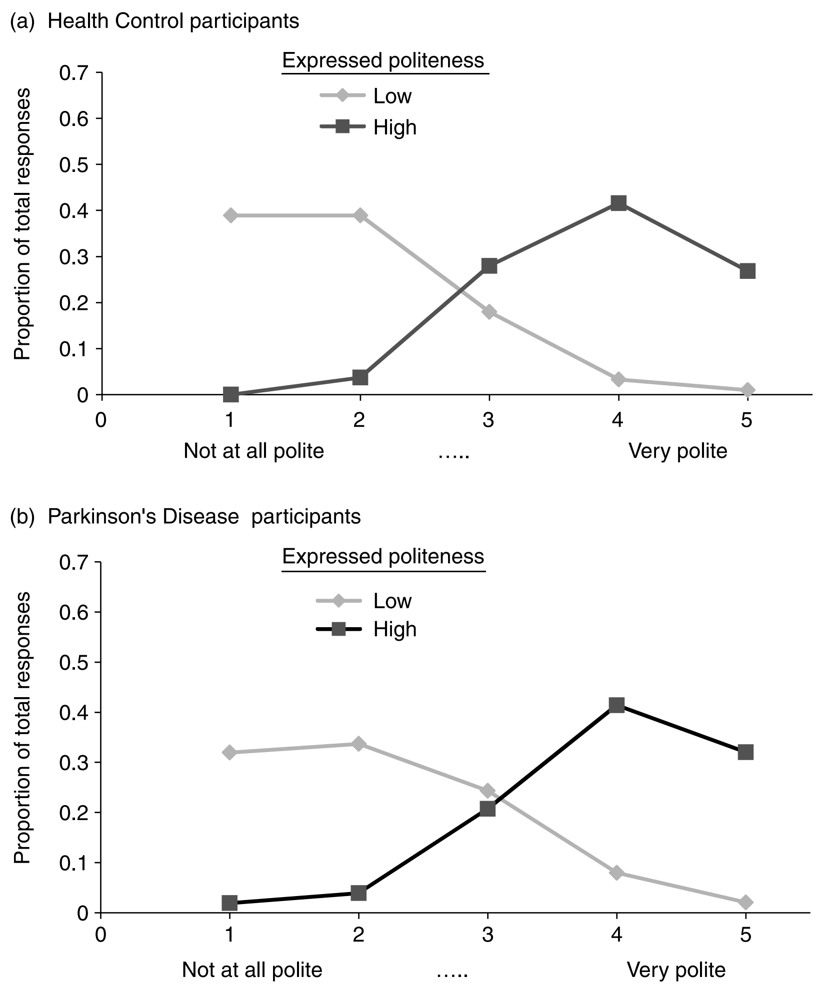

Figure 2. Sensitivity of healthy control (HC) listeners and listeners with Parkinson's disease (PD) to two levels of speaker politeness (high and low) according to the relative frequency of ratings assigned at each interval of a five-point scale.

Relationship between attitude ratings and other performance variables

To explore whether the ability to rate speaker attitudes bore a relationship to other performance measures gathered for our PD group, we first inspected the performance of individual PD patients on each attitude rating task in a relatively qualitative manner. Using the mean ratings of the HC group assigned to 'high' ($M = 4.1$) vs. 'low' ($M = 1.5$) levels of confidence as a reference point (mean difference = 2.6), we found that four of the PD patients (PD8, PD11, PD12, PD16) diverged notably from the expected pattern with a difference in conditional ratings that was less than half of that observed for the HC group. For politeness, three PD participants (PD12, PD13, PD15) appeared to perform much worse on this task in that they differentiated 'high' and 'low' politeness utterances by a margin less than half of that observed for the HC group ($M = 3.9$ for 'high' -1.9 for 'low' $= 2.0$ mean difference). It was noted that many of the affected patients had working memory scores in the lower half of the PD distribution, although there were notable exceptions, and only one of these PD patients was depressed (PD12). No other obvious relationships could be discerned between individual performance on the attitude rating tasks and the background measures.

As a second step, group performance in our confidence or politeness rating task was associated with performance for judging emotional prosody (as predicted by our main hypothesis). As a central measure of emotional prosody comprehension, we used the overall accuracy of the PD group (% correct responses) for identifying seven distinct emotions from emotionally inflected pseudo-utterances as reported in Table 1 (see also results of 'pure prosody' task described by Dara *et al.*, 2008). To transform our attitude ratings data to a comparable measure, we again focused on those stimuli representing each end of our two attitude continua (i.e. 'high' and 'low' confidence; 'high' and 'low' politeness) and recoded the responses of each PD participant to estimate their accuracy for identifying each speaker's attitude (in % correct). 'High' tokens were graded as correct within each task if the subject assigned a '4' or '5' to that item, and 'low' tokens were classified as correct if a '1' or '2' response was given. The correct responses for high and low items were then averaged in each task to achieve a measure of correct performance in each attitude rating task overall.

Pearson correlations of the accuracy scores for identifying emotional prosody, speaker confidence and speaker politeness revealed a strong relationship between emotional prosody and confidence rating for listeners in the PD group ($r = .74, p < .05$), and a similar trend for participants in the HC group ($r = .42$, *NS*). There was no discernable relationship between accuracy on the politeness task and either the emotional prosody or the confidence tasks for either group ($p > .05$). In a final analysis, the PD group's accuracy in the two attitude tasks was examined in relation to their performance on a subset of neuropsychological tests: working memory/listening span (words recalled), forward Digit Span (span attained), Benton face recognition (% correct), Benton phoneme discrimination (% correct) and Tower of London (initiation time). There was a positive relationship between working memory (listening span) and accuracy on the politeness rating test ($r = .55$, $p < .05$). No additional correlations with any of the neuropsychological performance measures were observed.

Discussion

To date, the effects of brain damage on decoding attitudinal states from speech prosody have been largely unexplored. As a point of departure, we considered how PD patients interpret prosodic cues that convey degrees of confidence and politeness, two distinct attitudes common to everyday discourse. In general, our findings revealed that the PD patients performed both experimental tasks in a manner that was not wholly comparable with the performance of healthy participants matched for age and education and who also resembled the PD patients on many traditional cognitive evaluation tasks (e.g. dementia rating, Tower of London). Group-related differences were especially prevalent for judging the intended confidence and not the politeness of speakers from prosodic cues as discussed below.

Understanding prosodic attitudes in PD

In the confidence rating task, there was evidence that listeners with and without PD varied in how they interpreted utterances conveying a high, moderate and low level of speaker confidence, and the performance of these two groups differed in the confidence rating task overall based on the relative frequency distribution of responses. In particular, the PD patients appeared to be less sensitive to tokens that contained overt prosodic cues that signalled that the speaker was very confident or very doubtful ('low' confidence) as judged by the healthy listeners (review Figure 1). In line with our predictions, this finding suggests that many participants with PD demonstrated a reduced sensitivity to prosodic indicators of speaker confidence, since our stimuli did not contain verbal information that could be used to render a correct interpretation. Nonetheless, both listener groups showed a similar, broad capacity to differentiate utterances conveying high, moderate and low speaker confidence based on the mean ratings assigned to tokens in each category. Thus, our different measures imply that the PD patients could detect graded differences in the intended confidence of speakers from prosody, but they tended to be less precise in their interpretations relative to healthy adults without brain damage.

In contrast, while there was some evidence that the PD group differed from healthy listeners in their sensitivity to vocal cues conveying 'low' politeness (impoliteness), the overall distribution of ratings assigned to the politeness stimuli by the two groups was highly similar. Moreover, the mean ratings indicated that both groups interpreted the prosodic significance of politeness cues in a comparable manner: utterances associated with a high rather than a low pitch were invariably perceived as more polite by all participants in agreement with the literature (Brown & Levinson, 1987; Loveday, 1981). Thus, our data revealed no indications that the PD participants failed to understand the intended politeness of speakers from prosodic attributes of speech, despite the fact that this group was impaired for rating confidence levels and for recognizing emotions from prosody alone (Dara *et al.*, 2008).

It is perhaps informative that the ability of our PD group to recognize emotional prosody correlated strongly with the ability to rate speaker confidence but not politeness. As argued by Pell (2007), the manner in which prosody operates to convey discrete emotions (e.g. anger, happiness) and speaker confidence is likely to bear a strong resemblance at initial stages of processing the acoustic cues of these expressions. In both cases, the underlying meanings are encoded by multiple prosodic parameters (i.e. interactive changes in pitch, loudness, rhythm), which combine over the course of the utterance to signal the intention of the speaker. In contrast, although politeness can be signalled by different vocal parameters, it appears likely that the polite/impolite distinction can usually be inferred in a relatively categorical manner by attending only to the relative height or direction of a speaker's pitch movements, that is, by the 'shape' of the intonation contour (Scherer, Ladd, & Silverman, 1984). The probability that our confidence stimuli were differentiated by a larger set of acoustic parameters than the politeness stimuli was confirmed by acoustic analyses of the stimuli presented in each attitude condition, as shown in Table 2.

Thus, one can reason that prosodic deficits in our PD group were largely prevalent in conditions that necessitated continuous and detailed listener analysis of ongoing prosodic changes in the utterance; this deficit precluded sensitive interpretations about the emotion expressed by the speaker (Dara *et al.*, 2008) and at least one attitudinal state (confidence) by individuals in the PD group. The observation that three of the four PD patients studied by Dara *et al.*, who performed outside the HC group range for recognizing emotional prosody, were impaired for judging speaker confidence using the same criteria lends support to the idea that the *source* of impairment in these two comprehension tasks may have been common. The related notion that PD patients are often unimpaired for rendering judgements of prosody when it encodes categorical meanings in speech, such as marking differences in lexical stress (e.g. hot DOG vs. HOT dog) and perhaps speaker politeness, is also well supported by the literature (Pell, 1996; Scott, Caird, & Williams, 1984). Alternatively, another acoustic explanation is possible for these findings: since speech rate was instrumental for differentiating levels of confidence but not politeness, the PD group may have experienced more selective difficulties to use temporal/speech time information for interpreting speaker intentions from prosody. This claim has been made previously in a study of vocal emotion recognition by PD patients in which duration and pitch cues of the stimuli were systematically varied (Breitenstein, Van Lancker, Daum, & Waters, 2001). Future investigations of PD patients will need to examine additional contexts in which prosody conveys meaningful contrasts in speech and the role of specific acoustic parameters in each context to build constructively upon these arguments.

Irrespective of the source of their prosodic deficits, it should be emphasized that difficulties in understanding speaker attitudes by our PD patients tended to be relatively mild in many conditions, at least for non-demented patients who were in the early (mild–moderate) stages of PD, medicated and not clinically depressed in most cases. Interestingly, in a related study of nine patients with focal right hemisphere strokes (Pell, 2007), patients with cortical lesions exhibited a similar misuse of prosody for understanding confidence but not politeness when compared with healthy listeners, although the *severity* of their impairments for rating speaker confidence was considerably greater (both in terms of the mean ratings assigned and their distribution across the three confidence levels; see Pell, 2007). In fact, there is often overlap in the conditions which negatively affect the performance of PD and right hemisphere-damaged patients on prosody tasks, although the nature and severity of the deficits observed for each population is presumed to be distinct (Borod *et al.*, 1990; Breitenstein, Daum, & Ackermann, 1998; also compare Pell, 1996 with results of Pell & Baum, 1997). These observations may reflect how different structures within a neural network devoted to prosody are affected by selective damage to the cortical vs. subcortical levels.

Basal ganglia contributions to prosody decoding

At the level of the neocortex, a growing literature suggests that the right *and* left hemispheres (bilateral temporo-frontal regions) co-operate to allow for complex representational processing of prosodic speech cues, including vocal expressions of emotion (Schirmer & Kotz, 2006). As noted earlier, there is also compelling evidence that the basal ganglia frontostriatal pathways serve a vital and potentially specialized role in the processing of vocal emotions following neuropsychological studies of PD patients (Breitenstein *et al.*, 2001), Huntington's disease patients (Speedie *et al.*, 1990), and patients with focal basal ganglia lesions (Cancelliere & Kertesz, 1990). The results of functional neuroimaging studies promote similar claims that the basal ganglia are somehow *directly* implicated in the processing of emotional prosody (Kotz, Meyer, Alter, Besson, von Cramon, & Friederici, 2003).

As argued previously, it is possible that the basal ganglia play a specialized role in the decoding of vocal cues to emotion and certain attitudes because these tasks involve the extraction of meaning from *sequential* representations in the vocal channel (Pell & Leonard, 2003; Meyer *et al.*, 2004). It is well accepted that the striatum participates in many cognitive domains (Brown & Marsden, 1998) and there are various theories about the direct involvement of basal ganglia structures in particular aspects of cognition and communication (Crosson, 1985; Ullman *et al.*, 1997). With respect to prosody, the striatum may be well suited to 'bind' temporally evolving events composed of sequential information in speech (Pell & Leonard, 2003) as part of a broader capacity to engage in different aspects of time perception and timing behaviours (e.g. Harrington, Haaland, & Hermanowicz, 1998; Rao, Mayer, & Harrington, 2001). Although our new findings do not furnish a direct test of this hypothesis, the observation that PD patients were impaired for processing speaker attitudes that were derived from complex vocal sequences in the speech signal (i.e. speaker confidence) is consistent with the hypothesized role of the basal ganglia for sequential processing in the auditory modality. One can speculate that this critical, supporting function of the basal ganglia facilitates sensitive interpretations of prosodic expressions at the level of the neocortex by refining the flow of incoming information through segregated cortico-subcortical loops (Hochstadt, Nakano, Lieberman, & Friedman, 2006).

The fact that our PD patients did not show serious cognitive deficits, and that their neuropsychological performance did not generally predict their performance on the attitude rating tasks, implies that neuropathological changes in PD can have a primary influence on prosodic communication, which is not secondary to other neuropsychological deficits. In other areas of research, it is recognized that frontostriatal dysfunction in PD often leads to working memory or related 'frontal lobe' impairments which can have a secondary impact on certain communication abilities, such as complex syntactic processing and non-literal language processing (Grossman *et al.*, 2002; Monetta & Pell, 2007). However, evidence of a strong relationship between working memory performance and the ability to process prosodic attitudes was incomplete for our data, as has been concluded previously for emotional prosody (Breitenstein *et al.*, 2001; Yip *et al.*, 2003). Thus, it can be claimed here that difficulties in understanding the emotions and attitudes of a speaker from prosody represent one of the primary neuropsychological consequences of PD (i.e. due to changes within the basal ganglia and their output). Nonetheless, it bears noting that many of the most impaired PD patients had reduced working memory scores and working memory performance was also correlated with the ability to rate speaker politeness; thus, the role of working memory, executive functions and mood should continue to be monitored closely in prosody research when studying patients with PD.

One possible limitation of our study was that we evaluated how PD patients interpret speakers attitudes from isolated prosodic cues using language-like 'pseudo-utterances', without concurrently testing their ability to understand these meanings from the verbal content of an utterance (for example, if presented '*The book is on the top shelf*' spoken in a confident or doubtful voice). There are reasons to believe that our PD group would not have experienced serious difficulties in understanding speaker attitudes when the verbal content supplied unambiguous clues about the intended meaning. Individuals in the PD sample under study could accurately use verbal information, although not prosody, to identify basic emotions from similar utterances (Dara *et al.*, 2008) and this pattern is also strongly indicated by the existing literature on PD (Blonder *et al.*, 1989; Breitenstein *et al.*, 1998; Pell, 1996; Pell & Leonard, 2003). Thus, deficits in our PD group likely represented a selective misuse of prosody for understanding speaker emotions or attitudes in this study. At the same time, the fact that many PD patients can successfully interpret emotions from explicit language content is encouraging knowledge for clinicians, as this could serve as a point of departure for designing intervention strategies that could develop the skills necessary for PD patients to compensate for prosodic difficulties.

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