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<th><strong>Title</strong></th>
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<td><strong>Other Contributor(s)</strong></td>
<td>University of Hong Kong</td>
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Intonation in Cantonese Parkinson’s disease: questions versus statements

So Yee Shan, Susanne

A dissertation submitted in the partial fulfillment of the requirements for the Bachelor of Science (Speech and Hearing Sciences), The University of Hong Kong, June 30, 2008.
Abstract

This study investigated the production of question-statement contrast by Cantonese Parkinson’s disease (PD) speakers. Sentences produced by fourteen PD speakers as questions or statements were presented to twenty listeners. The perceptual accuracy of question intonation produced by PD speakers was lower than that previously reported for non-impaired speakers. The results of the acoustic analysis showed that some PD speakers marked question intonation using an overall rise in fundamental frequency (F0) and rise in F0 at the final syllable while others did not have clear acoustic markers to signal the question-statement contrast. None of the PD speakers made use of prosodic cues other than F0 to signal the question-statement contrast. There were some clear relationships between perceptual accuracy and acoustic variables.
Introduction

Intonation is considered an important component of the linguistic structure of many languages (Liberman, 1967). Different intonation could affect the meaning conveyed in a sentence. One common example is the production of questions versus statements. Questions are produced with a rising intonation while statements are produced with a falling intonation in most languages including Cantonese (Bauer & Benedict, 1997; Eady & Cooper, 1986; Liberman, 1967; Ohala, 1978).

The rising intonation in questions and falling intonation in statements is produced by a change in fundamental frequency (F0) contour. In addition to the use of F0 contour, other prosodic cues such as loudness and syllable duration are also used in producing the question-statement contrast in different languages. In English, Fry (1958) has showed that duration was used in marking the yes-no question-statement contrast while more recent study from Patel (2002a) has also showed that non-impaired speakers produced questions with an overall rise in F0 contour, a sharp rise in the F0 contour of the final syllable, lengthened duration and increased intensity of the final syllable. Studies in Mandarin also showed that question intonation was produced with higher intensity and with a longer duration in the final syllable (Ho, 1977; Yuan, 2004). These implied that a combination of prosodic cues could be used in marking the question-statement contrast.

Despite the possibility of using a combination of prosodic cues, a rising F0 contour is
still the most important cue in marking the question-statement contrast. Patel (2002b) found that removal of F0 contour cue reduced the accuracy in perception of question-statement contrast to a much greater extent than that of removal of durational cue. This study indicated that people tended to focus on the F0 contour more than on the durational cue in perception of the question-statement contrast. When looking at F0 contour cue, Ma, Ciocca, & Whitehill (2006a) found that the accuracy in perception of question-statement contrast with the presentation of the final syllable only or the complete sentence were significantly higher than that with the presentation of the carrier only. This study indicated that the rising F0 contour in the final syllable in questions is more important than the overall rise of F0 contour in the complete sentence in marking the contrast in Cantonese.

When the use of prosodic cue particularly the change of F0 contour is so essential in marking the question-statement contrast, one may wonder whether a person with speech impairment particularly in the prosodic aspect could mark the contrast. Parkinson’s disease (PD), which results from the degeneration of the basal ganglia and substantia nigra, is often characterized by dysprosody (Darley, Aronson & Brown, 1969a, 1969b, 1975). PD is a progressive neurological condition which affects patients in a range of motor and non-motor functions (Scott, 1997). The rigidity in muscle tone, slow initiation and execution of movement in PD patients could lead to difficulty in prosody control (Darley et al, 1975). That is why hypokinetic dysarthria, which is associated with PD disease, has prominent perceptual
characteristics of monotone, monoloudness and slowed rate (Darley et al., 1969a, 1969b, 1975).

Penner, Miller, Hertrich, Ackermann, & Schumm (2001) compared the intonation contours of non-impaired and PD native German speakers’ speech using acoustic measurements. The results showed that PD patients had a reduced peak height of F0. Nevertheless, some English-language studies have shown that patients with severe dysarthria were still able to mark the question-statement contrast though they had reduced prosodic control and thus a smaller variation in intonation (Le Dorze, Ouellet, & Ryalls, 1994; Patel, 2002b). Patel (2002b) investigated severe dysarthric patients’ abilities in marking the question-statement contrast. It was found that patients with severe dysarthria might make use of prosodic cues other than F0 contour such as durational cue and loudness cue to a greater extent as these cues change more slowly over time and they could have better control of them. Another study from Patel (2003) investigated the acoustic characteristics of the question-statement contrast in severe dysarthria resulted from cerebral palsy and compared them with non-impaired speakers. It was found that non-impaired speakers primarily used F0 and duration while dysarthric speakers used F0, duration and intensity to mark question-statement contrast. Dysarthric speakers produced question intonation with a higher peak F0 and average F0 than statement intonation. However, non-impaired speakers had a greater extent of rising F0 at the final syllable for question intonation than dysarthric speakers.
This showed that dysarthric speakers’ marked question-statement contrast in a way similar to non-impaired speakers but their abilities in marking the contrast might be impaired due to the impaired prosodic control.

These previous studies were conducted with speakers of non-tonal languages. Cantonese is a tonal language in which the same word with only a tonal contrast could represent a very different meaning (Bauer & Benedict, 1997). Cantonese patients with dysarthria have to control lexical tone and intonation at the same time in daily communication. As both production of tone at syllabic level and production of intonation at sentence level make use of the F0 variation, prosodic impairment in Cantonese-speaking patients could affect them to a greater extent than that of non-tonal language speaking patients. This raises the interest in investigating the effect of impaired control of prosody in Cantonese-speaking dysarthric patients.

There are some related studies in this area. Wong and Diehl (1999) found that Cantonese PD speech has a reduced tonal space, which refers to the pitch range within which all tones fall. Because of this, the tones produced by PD patients were more difficult to be identified than those produced by non-impaired speakers. This showed that the production and perception of Cantonese lexical tone are affected by dysarthria. A perceptual profile of Cantonese hypokinetic dysarthric speech published by Whitehill, Ma, & Lee (2003) showed that monopitch was a speech dimension that was severely affected while tone production was
relatively less affected. This implied that there might be different underlying mechanisms or control in the production of lexical tone and intonation which further ascertains the need for investigating the intonation of Cantonese-speaking dysarthric patients.

Ma et al. (2006a) investigated the significance of different perceptual cues in marking the question-statement contrast by non-impaired Cantonese speakers. They showed that the rising F0 contour in the final syllable in questions is more important than the overall rise of F0 contour in the whole sentence, and that tones had an effect on intonation identity. In that study, listeners were asked to judge whether stimuli were a question or a statement. The stimuli were presented either in complete sentence, in carrier only or final syllable only and different set of tones were included at final syllable. Mean perceptual accuracy of intonations were found in this study and it was found that statements were more accurately perceived than questions. Another study from Ma, Ciocca, & Whitehill (2006b) which investigated the effect of intonation on Cantonese lexical tone showed that the F0 level of questions was generally higher than that of statements regardless of the tone, while the difference in duration of a specific tone in questions versus statements was not significant.

The present study used the findings of Ma et al. (2006a) to begin to look at PD patients by following the same procedure. The aims were to investigate the production of question-statement contrast by Cantonese PD patients in both perceptual and acoustic aspects and to compare the difference in perceptual accuracy of intonation between PD patients’
speech and normal speech. As pitch is a perceptual correlate of frequency while monopitch is
correlated to a flattened F0 contour (Bunton, Weismer, & Kent, 2000; Raphael, Borden, &
Harris, 2007), F0 which reflects pitch and standard deviation of F0 (SDF0) which reflects F0
variability were chosen to be analyzed in this study. In addition, intensity ratio of the first and
final syllable and duration of whole sentence were also analyzed in this study to examine the
use of different prosodic cues by PD patients.

Method

Participants

Fourteen native Cantonese-speaking PD patients, five females and nine males, with
dysarthria participated in this study as speakers. They were recruited from the Hong Kong
Parkinson’s Disease Association. The age of the speakers ranged from 50 to 73 years with a
mean of 61.0 years. Except for one participant, who had Parkinsonism after cerebral vascular
accident, all were diagnosed as having idiopathic Parkinson’s disease by a neurologist. All
speakers were judged to demonstrate hypokinetic dysarthria by two qualified speech
therapists, who also provided a severity rating (mild, moderate, severe), based on a reading
passage sample.

All the speakers had normal oral-peripheral structure, normal hearing ($\leq 40$dB HL in at
least one ear, at 500, 1000, 2000 and 4000Hz), and normal language ability as screened by a
test adapted from Cantonese Aphasia Battery (Yiu, 1992) (Appendix A).
Twenty undergraduate students in the Division of Speech and Hearing Sciences at the University of Hong Kong were recruited as listeners. They were all native Cantonese speakers and were reported to have normal hearing.

Speech data collection

As this study aimed at comparing the intonation of PD patients with those of non-impaired speakers as reported by Ma et al. (2006a), the stimuli used were the same as those used by Ma et al. (2006a) (Appendix B). To summarize, a carrier phrase ‘This word is \textit{X}’ (/lei55 kɔ33 tsi22 hɐi22 X/) was used. \textit{X} was words with only a tonal contrast. Eighteen words were formed by the six tones of the three syllables /jɐu/, /jɨ/, and /sɨ/. The carrier phrase was produced by the speakers as either a question or a statement by the speakers through the simulated conversation technique designed by Ma et al (2006a). A total of 36 stimuli were produced as a result. Another two carrier phrases ‘\textit{X} is difficult to write’ (X tsi22 hou25 lan21 sɛ25) and ‘Write the \textit{X} word first’ (sɛ25 kɔ33 X tsi22 sin55) were also used to form 24 stimuli with the syllable /sɨ/. These 24 stimuli only served as distracters to avoid any undesirable effects resulting from repeated production of the same sentence structure and they were not used in the later perceptual task and data analysis.

Recordings of the stimuli were made in a quiet room with ambient noise level lower than 42.6 dB except one which was at 50.5 dB. The computer software Audacity v1.2.6, a Direct Mix USB 3 Soundcard and an AKG C 525 S or Shure SM48 unidirectional
microphone with a mouth to microphone distance of 10 cm were used for the recordings. The
dialogues were presented visually on the screen of a Machintosh PowerBookG4 running a
HyperCard program. The speakers and the investigator were engaged in a pretend
conversation in which the investigator initiated and the speaker answered. The sequence of
the stimuli presented was randomized across subjects by the HyperCard program. The stimuli
were then recorded onto the computer and the loudness of all sound files was adjusted to
ensure overall similarity. Stimuli from two speakers were repeated in the later perceptual task
for establishing intra-listener reliability.

Perceptual task

The listening experiment was carried out in a sound-attenuated room (IAC sound booth).
The speech materials were delivered to the listeners through a Sennheiser HD 212Pro
headphone connected to an Apple Macintosh G4 computer. The sequence of presentation of
stimuli was randomized by the HyperCard program. All stimuli were presented once unless
the listener clicked the ‘repeat sound’ button for listening a second time. Listeners made the
judgment of question versus statement by clicking a button on the screen presented by the
HyperCard program. There were a total of 576 trials and the experiment took about 45
minutes for each listener.

Acoustic analysis

Acoustic analysis was performed using Praat software (Version 4.4.13, Boersma &
Weenink, 2006) to measure the F0, the intensity and the duration of each word. Each word was segmented visually from a wideband spectrogram and an amplitude waveform display. The F0 from nine evenly-spaced time points of each word were estimated using an autocorrelation algorithm; five points were used for later analysis (0%, 25%, 50%, 75% and 100% of the total duration). Manual measurements from the amplitude waveform were used for F0 estimates which were largely different from adjacent time points. The intensity of the first and final syllable was measured using Praat built-in function. The duration of each word was calculated by the difference in time between the 0% and 100% time points.

To establish intra- and inter-rater reliability, the acoustic analysis of two speakers was repeated by the investigator and a second examiner.

Data analysis

The percentages of correct identification of intonation were calculated for each speaker and the means were calculated as the overall perceptual accuracy for each of the two intonations. Wilcoxon matched-pair test was used to compare the perceptual accuracy between questions and statements as the homogeneity of variance was violated. The speakers were then grouped into three groups according to the perceptual accuracy for questions for later analysis.

The average F0, SDF0, intensity ratio of the first and final syllable, duration and change in F0 in final syllable (F0 at 100% time point minus F0 at 0% time point) of each stimulus
were then calculated. The group averages for two intonations and for each speaker were also
calculated for later analysis. The stimuli were then classified into three groups: ‘perceived as
questions’, ‘perceived as statements’ and ‘equally likely to be perceived as questions or
statements’ by binomial distribution test. The stimuli were judged as question or statement by
20 listeners. According to the results of the binomial distribution test, the probability of
obtaining 14 same answers by chance was less than 5 out of 100 trials ($p < 0.05$). Therefore,
stimuli which were judged as questions by 14 or more listeners were classified as ‘perceived
as questions’. Similarly, stimuli which were judged as statements by 14 or more listeners
were classified as ‘perceived as statements’. All other stimuli were classified as ‘equally
likely to be perceived as questions or statements’.

The group averages in average F0, SDF0, intensity ratio of the first and final syllable,
duration and change in F0 in final syllable for these three groups were calculated for analysis
on the difference between the stimuli perceived as questions and those perceived as statement
regardless of their originally intended intonation.

Intra- and inter-rater reliability

Intra-listener reliability was determined by calculating the agreement among the 72
repeated stimuli from two speakers. Inter-listener reliability was determined by calculating
point-to-point reliability in which the percentage correct of each stimulus with reference to
the most often perceived intonation for each listener was calculated. The intra- and
inter-listener reliability were 95.00% and 94.86%, respectively.

Intra- and inter-rater reliability for acoustic measurements were determined by Pearson product-moment correlation. Intra-rater reliability was 0.99, 0.98, 0.98 and 0.99 for mean F0, SDF0, intensity ratio and duration, respectively. Inter-rater reliability was 0.995, 0.98, 0.98 and 0.99 for mean F0, SDF0, intensity ratio and duration, respectively. The mean difference and SD were shown in Appendix C.

Results

Perceptual accuracy

The severity of dysarthria, the mean perceptual accuracy for questions and statements for each speaker, as well as the mean for questions and statements across speakers are shown in Table 1. The perceptual accuracy for questions across speakers ranged from 0.56% to 96.11% (mean = 44.86%) while the perceptual accuracy for statements ranged from 86.67% to 100% (mean = 95.83%). The average perceptual accuracy for statements was significantly higher than that for questions ($T = 0, p < 0.05$). As the range of perceptual accuracy for questions was large, the speakers were classified into three groups according to the perceptual accuracy for questions for further analysis: Group A: high perceptual accuracy (above 70%); Group B: fair perceptual accuracy (45-60%); Group C: low perceptual accuracy (below 10%). Although no clear relationship was found between the severity rating and perceptual accuracy for intonations for the speakers, the two speakers with moderately severe dysarthria were in
group C while all the speakers in group A had mild dysarthria only.

Table 1. Perceptual accuracy according to intonations (questions and statements) for each speaker and the average accuracy for each intonation.

<table>
<thead>
<tr>
<th>Speakers</th>
<th>Gender</th>
<th>Age</th>
<th>Severity</th>
<th>Perceptual accuracy</th>
<th>Group average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Question</td>
<td>Statement</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Question</td>
<td>Statement</td>
</tr>
<tr>
<td>Group A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WCM</td>
<td>M</td>
<td>58</td>
<td>1</td>
<td>96.11%</td>
<td>98.06%</td>
</tr>
<tr>
<td>LCO</td>
<td>F</td>
<td>73</td>
<td>2</td>
<td>82.22%</td>
<td>86.67%</td>
</tr>
<tr>
<td>YYH</td>
<td>M</td>
<td>50</td>
<td>1</td>
<td>81.94%</td>
<td>93.06%</td>
</tr>
<tr>
<td>KMP</td>
<td>F</td>
<td>59</td>
<td>1</td>
<td>79.44%</td>
<td>98.61%</td>
</tr>
<tr>
<td>Group B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCW</td>
<td>M</td>
<td>61</td>
<td>1 to 2</td>
<td>58.61%</td>
<td>99.72%</td>
</tr>
<tr>
<td>TKY</td>
<td>F</td>
<td>60</td>
<td>1 to 2</td>
<td>58.33%</td>
<td>98.89%</td>
</tr>
<tr>
<td>CWY</td>
<td>M</td>
<td>58</td>
<td>1</td>
<td>53.61%</td>
<td>99.44%</td>
</tr>
<tr>
<td>HYK</td>
<td>M</td>
<td>59</td>
<td>1</td>
<td>53.33%</td>
<td>99.17%</td>
</tr>
<tr>
<td>LPS</td>
<td>M</td>
<td>60</td>
<td>1</td>
<td>45.00%</td>
<td>91.67%</td>
</tr>
<tr>
<td>Group C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MHP</td>
<td>M</td>
<td>61</td>
<td>3</td>
<td>9.44%</td>
<td>92.50%</td>
</tr>
<tr>
<td>NKF</td>
<td>M</td>
<td>70</td>
<td>3</td>
<td>5.28%</td>
<td>91.67%</td>
</tr>
<tr>
<td>LLY</td>
<td>F</td>
<td>57</td>
<td>1</td>
<td>2.78%</td>
<td>95.83%</td>
</tr>
<tr>
<td>KWK</td>
<td>M</td>
<td>58</td>
<td>1</td>
<td>1.39%</td>
<td>96.39%</td>
</tr>
<tr>
<td>MSK</td>
<td>F</td>
<td>60</td>
<td>1</td>
<td>0.56%</td>
<td>100.00%</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td>44.86%</td>
<td>95.83%</td>
</tr>
</tbody>
</table>

Note: Severity: 1 = mild, 2=mild-to-moderate, 3=moderate

Acoustic analysis

The average F0, SDF0, intensity ratio of the first and final syllable, duration and change in F0 in final syllable (F0 at 100% time point minus F0 at 0% time point) across intonations for the three groups with different perceptual accuracy for questions are shown in Table 2.

Mean fundamental frequency

The mean F0 of questions (170.38Hz) was higher than that for statements (163.63Hz) for the group overall. The average difference in mean F0 between question and statement was not very large (6.75Hz). However, the average difference in mean F0 in Group A (13.13Hz) was larger than that of Group B (6.21Hz), whereas Group C (0.91Hz) had the smallest
difference.

**Standard deviation of F0, intensity ratio, duration**

The average SDF0, intensity ratio and duration between question and statement were very similar across all three groups. No obvious differences were observed.

**F0 change in the final syllable**

The F0 change was calculated by subtracting the mean F0 at 0% time point from the mean F0 at 100% time point. Therefore, a positive number reflected a rising F0 contour while a negative number reflected a falling F0 contour. As shown in Table 2, the F0 change in questions was higher than that of statements. The average F0 change in questions (35.06Hz) and statements (-1.31Hz) reflected a rising F0 contour in questions and a slightly falling F0 contour in statements. The degree of rising in F0 contour was greater in Group A (63.32Hz) than in Group B (40.29Hz). For group C, there was virtually no rise for questions and no obvious difference in F0 change across intonations.

Table 2. Mean F0, SDF0, intensity ratio of the first and final syllable, duration and change in F0 in final syllable across intonations for three groups with high, fair and low perceptual accuracy.

<table>
<thead>
<tr>
<th></th>
<th>Mean F0 (Hz)</th>
<th>SD F0</th>
<th>Intensity ratio</th>
<th>Duration (s)</th>
<th>F0 change in final syllable (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q</td>
<td>S</td>
<td>Diff.</td>
<td>Q</td>
<td>S</td>
</tr>
<tr>
<td>Group A</td>
<td>177.03</td>
<td>163.90</td>
<td>13.13</td>
<td>36.74</td>
<td>35.12</td>
</tr>
<tr>
<td>Group B</td>
<td>152.21</td>
<td>146.01</td>
<td>6.21</td>
<td>30.29</td>
<td>30.17</td>
</tr>
<tr>
<td>Group C</td>
<td>181.91</td>
<td>180.99</td>
<td>0.91</td>
<td>40.49</td>
<td>41.38</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>170.38</strong></td>
<td><strong>163.63</strong></td>
<td><strong>6.75</strong></td>
<td><strong>35.84</strong></td>
<td><strong>35.56</strong></td>
</tr>
</tbody>
</table>
The stimuli produced by all speakers were classified into three groups: ‘Perceived as questions’, ‘Perceived as statements’ and ‘Equally likely to be perceived as questions or statements’, using binomial distribution test, regardless of the original intended intonations. The average F0, SDF0, intensity ratio of the first and final syllable, duration and change in F0 in final syllable across perceived intonations are shown in Table 3.

The mean F0 of stimuli perceived as questions was higher than that of stimuli perceived as statements. The F0 difference between stimuli perceived as questions and stimuli perceived as statements was 6.93Hz. The intensity ratio and duration across the perceived intonations were very similar. The SDF0 in stimuli perceived as statements (37.28Hz) was slightly higher than that of those perceived as questions (35.29Hz). The F0 change in stimuli perceived as questions (66.69Hz) was higher than that of those equally likely to be perceived as questions or statements (41.81Hz); stimuli perceived as statements (-1.78Hz) had the least change. The positive F0 change in perceived questions and stimuli equally likely to be perceived as questions or statements reflected a rising F0 contour while the negative change in perceived statements reflected a slightly falling F0 contour.

Table 3. Mean F0, SDF0, intensity ratio of the first and final syllable, duration and change in F0 in final syllable across perceived intonations

<table>
<thead>
<tr>
<th></th>
<th>Mean F0 (Hz)</th>
<th>SDF0</th>
<th>Intensity ratio</th>
<th>Duration (s)</th>
<th>F0 change in final syllable (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived Question</td>
<td>175.66</td>
<td>35.29</td>
<td>1.04</td>
<td>1.09</td>
<td>66.69</td>
</tr>
<tr>
<td>Perceived Statement</td>
<td>168.73</td>
<td>37.28</td>
<td>1.08</td>
<td>1.15</td>
<td>-1.78</td>
</tr>
<tr>
<td>Equally likely to be</td>
<td>168.58</td>
<td>33.35</td>
<td>1.04</td>
<td>1.20</td>
<td>41.81</td>
</tr>
<tr>
<td>perceived as Q or S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Discussion

This study investigated the production of question-statement contrast by Cantonese PD patients using both perceptual and acoustic analyses. This issue has been looked at in non-impaired Cantonese speakers and normative data has been established. As shown in Table 1, statements were more accurately perceived than questions which was consistent with the findings of Ma et al. (2006a) on perception of question-statement contrast produced by non-impaired Cantonese speakers. By qualitative comparison, the mean perceptual accuracies of statements produced by non-impaired speakers (97.61%) (Ma et al., 2006a) and PD patients (95.83%) in the current study were similar. This indicated that the PD patients performed similar to non-impaired speakers in the production of statement intonation. However, the mean perceptual accuracy of questions produced by PD patients (44.86%) was much lower than that by non-impaired speakers (90.81%). Even the mean perceptual accuracy of Group A, which had the highest accuracy (83.93%), was lower than that of non-impaired speakers. This indicated that PD patients’ ability in marking question intonation was impaired.

In addition, it was found that the perceptual accuracies of question intonation varied greatly across speakers with a range from 0.56% to 96.11%. When each speaker’s severity rating of dysarthria and their respective perceptual accuracy in question intonation were compared, no perfect relationship was found. But generally speaking speakers with mild
dysarthria were associated with higher perceptual accuracies while those with relatively severe dysarthria were associated with lower perceptual accuracies for question intonation. This was concluded from the observation that the two speakers with moderately severe dysarthria (which were the most severe cases in this study) were in group C while all the speakers in group A had mild dysarthria only. The discrepant cases might have been due to the fact that severity was judged using a reading passage whereas sentence reading was used in the experiment. In addition, the perception of other speech symptoms such as voice quality could affect the perceptual judgment of severity or even prosody (Rosenbek and LaPointe, 1985).

The use of prosodic cues, particularly change in F0 contour, is essential in marking the question-statement contrast. The fact that PD patients have difficulty in prosody control, due to their rigidity in muscle tone, slow initiation and execution of movement (Darley et al, 1975), could be the reason for the low perceptual accuracy of question intonation. To further investigate the production of question-statement contrast by PD patients, several acoustic variables were analyzed in this study.

Normal people produce questions with an overall rise in F0 contour and sharp rise in F0 contour of final syllable (Patel, 2002a). Looking at the acoustic results of productions by PD patients (Table 2), the average mean F0 for question and statement intonation were 170.38Hz and 163.63Hz, respectively, with a difference of 6.75Hz. The overall higher mean F0 in
question intonation was in agreement with previous studies (Ma et al., 2006a; Patel, 2002a). However, the difference was small; this might have resulted from the impaired prosody control of PD patients. The small difference in mean F0 between question and statement intonation could contribute to the low perceptual accuracy of question intonation. This was supported by the findings that Group A, which had the highest perceptual accuracy in question intonation, presented with the largest difference in mean F0 while Group C, which had the lowest perceptual accuracy in question intonation, presented with the smallest difference in mean F0 among the three groups.

It was expected that the SDF0 of question intonation would be greater than that of statement intonation as SDF0 is an indicator of pitch variability (Bunton et al., 2000; Raphael et al., 2007). When looking at the SDF0 of question and statement produced by PD patients, the differences between the two intonations across the three groups were very small though Group A showed a slightly larger difference than Group B. Again, this might due to the difficulty in prosodic control due to rigidity in muscle tone in the laryngeal area in PD patients. The SDF0 in statement intonation produced by Group C was even slightly greater than that of question intonation. The possible reason was that PD patients’ poor laryngeal control might result in pitch break which could contribute to the high SDF0 in a stimulus. For example, pitch break was present in a statement produced by one PD speaker as shown in Appendix D. Hence, the lack of variation in SDF0 could be another cause for the lower
perceptual accuracy of question intonation produced by PD speakers than that produced by non-impaired speakers.

As the PD patients appeared to have difficulty in effectively using the mean F0 and SDF0 to mark the question-statement contrast accurately, the possibilities of use of intensity and durational cue were investigated. The intensity ratio between the first and final syllable and duration (duration of the whole stimulus was measured in the experiment) between question and statement intonations produced by PD patients were very similar across the three groups. This finding was different from previous studies in English and Mandarin which showed that loudness and duration (duration of the final syllable) were used in producing the question-statement contrast by non-impaired speakers (Fry, 1958; Ho, 1977; Patel, 2002a; Yuan, 2004). In these studies, questions were produced by relatively higher intensity and longer duration in final syllable. Moreover, this finding did not support other previous findings in English which suggested that patients with severe dysarthria might make use of prosodic cues like duration and loudness to mark the contrast, as these cues changed more slowly than F0 contour and hence might be easier to control (Patel, 2002b). The results from this study suggested that Cantonese-speaking PD patients might not make use of intensity or durational cues in marking the contrast as non-impaired English and Mandarin speakers and English speakers with severe dysarthric speakers did.

Although mean F0 seemed to be used by only some speakers to signal the
question-statement contrast and SDF0, intensity and duration did not appear to signal the difference between the two intonations, another parameter, the change of F0 in final syllable, could be examined. It is widely known that questions are produced with a rising intonation while statements are produced with a falling intonation and previous findings also showed that rising F0 contour was more important than durational cue in signaling the question-statement contrast (Bauer & Benedict, 1997; Eady & Cooper, 1986; Liberman, 1967; Ohala, 1978; Patel, 2002b). Moreover, the rising F0 contour in the final syllable is more important than the overall rise of F0 contour (Ma et al., 2006a). Therefore, the F0 change in final syllable was investigated in the present study. From the results, the mean F0 change in final syllable of questions and statements were 35.05Hz and -1.31Hz, respectively. This was in agreement with previous studies as a positive change indicated a rising contour while a negative change indicated a falling contour. This suggested that as a group, PD patients did manage to produce F0 change in the final syllable when marking the contrast. More interestingly, it was found that Group A patients, who had the highest perceptual accuracy, produced the largest positive F0 change in final syllable of question than the other two groups, which had lower perceptual accuracies.

In summary, PD patients produced acoustical differences in F0 change in final syllable but not SD F0, intensity and duration, across intonations. Some of them produced acoustical difference in mean F0 but some did not. The degree of difference in mean F0 and F0 change
in final syllable across intonations was related to the perceptual accuracy.

When looking at the five acoustic variables in stimuli perceived as questions and stimuli perceived as statements (Table 3), similar results were found. The differences between intensity ratio and duration across perceived intonations were small while the SDF0 in perceived statements was even slightly greater than that of perceived questions. The possible reason was the presence of pitch break due to poor laryngeal control as mentioned before.

The major differences between the two perceived intonations were in mean F0 and F0 change in final syllable, which was the same as in the analysis for intended intonations. The difference between mean F0 across perceived intonation was 6.93Hz, which was similar to the 6.75Hz difference across intended intonations. This was also consistent with the results from intended intonation as both Group A (high perceptual accuracy group) and Group B (fair perceptual accuracy group) had a difference of more than 6 Hz in mean F0 while Group C (low perceptual accuracy) had only a difference of 0.91Hz.

The F0 change in perceived questions and statements were 66.69Hz and -1.78Hz, respectively, which were again in agreement with the rising F0 contour for questions and falling F0 contour for statements. When comparing the degree of positive F0 change of perceived questions with intended questions, it was found that all the three groups had positive F0 change in intended questions smaller than perceived questions, while Group A had the nearest value (63.32Hz). Stimuli which were equally likely to be perceived as
questions or statements had a positive F0 change of 41.81Hz which was less than that of stimuli perceived as questions. This was consistent with the result from intended intonation as Group B had a perceptual accuracy of only 53.78% in question intonation though it had a positive F0 change of 40.29Hz in final syllable. This suggested that a greater positive F0 change was needed in signaling the question-statement contrast and many of the PD patients seemed to have difficulty to produce enough changes.

The results from this study indicated that the prosody of PD patients could vary greatly from one to another. It is not appropriate to assume that all PD patients manifested the same problems with prosodic control. Therefore, treatment should be planned according to individual needs. Providing training on pitch variation to PD patients might be beneficial to maintain or even improve their prosodic control.

The range of severity of patients included in this study was small. Further studies on the ability to mark question-statement contrasts across different severity of dysarthria should aim to include speakers with more severe dysarthria. Patel (2003)’s study had already looked at this in English-speaking speakers with severe dysarthria but limited investigation had been done on Cantonese-speaking speakers with severe dysarthria.

Conclusion

This study investigated Cantonese PD patients’ production of question-statement contrast using perceptual and acoustic analyses. The speakers mainly marked questions using
an overall rise in F0 and rise in F0 at the final syllable, similar to non-impaired speakers
(Bauer & Benedict, 1997; Eady & Cooper, 1986; Liberman, 1967; Ma et al., 2006a; Ohala, 1978; Patel, 2002a). However, their abilities to mark the question intonation were impaired, as reflected in the lower perceptual accuracy of questions compared with non-impaired speakers. The degree of difference in mean F0 and F0 change in final syllable produced to signal the question-statement contrast was related to the perceptual accuracy. In addition, Cantonese PD patients did not make use of prosodic cues other than F0 to signal the question-statement contrast. This is the first study to look at the production of question-statement contrast in Cantonese dysarthria which has important implications for the design of therapeutic intervention.
Acknowledgement

I would like to express my sincere thanks to my supervisor, Professor Tara Whitehill, and co-supervisor, Dr. Joan Ma, for their support and guidance; Professor Valter Ciocca for providing the Praat script for acoustic analysis; and the technical staff in the Division of Speech and Hearing Sciences for their help. I gratefully acknowledge the patients and the classmates who volunteered to take part in the study.
References


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Appendix A

Screening form

Personal information
Name: ______________________   Client no.: ______________________
Sex/Age: ____________________   Clinician: _______________________
Contact no.: __________________  Education: ___________________
Address: __________________________________________________________
Date: __________________________

Medical history
Onset of PD/years since diagnosed: _________________
Name of Medication: _______________________
Usual time of taking medicine: __________________________
Time of feeling the effect of medicine: _________________

Hearing screening
Pure tone audiometry (unmasked) air-conduction thresholds:

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>500Hz</th>
<th>1000Hz</th>
<th>2000Hz</th>
<th>4000Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left ear</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right ear</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

☐ Pass   ☐ Fail

Pass = 30 dB in at least one ear (if failed, do 40dB; if passed, do 25dB)

Oral peripheral examination
Facial      ☐ Normal   ☐ Abnormal: _______________________
Mandible    ☐ Normal   ☐ Abnormal: _______________________
Dental      ☐ Normal   ☐ Abnormal: _______________________
Lingual     ☐ Normal   ☐ Abnormal: _______________________
Palatal     ☐ Normal   ☐ Abnormal: _______________________
Aphasia screening test

(Adapted from the Cantonese Aphasia Battery (Yiu, 1992), which was adapted with permission from the Western Aphasia Battery (Kertesz, 1982))

Comprehension
A. Picture Pointing:
1. 火柴 (1) ________________  2. 花 (1) ________________
3. 飲橙汁 (1) ________________  4. 拍手 (1) ________________
5. 較剪 (1) ________________

B. Commands:
1. 舉起隻手 (1) ________________
2. 指吓張凳 (1) ________________
3. 指吓度門 (1) ________________
4. 用支筆 (1) ________________
5. 指吓本書 (1) ________________

C. Yes/No Questions:
1. 你係咪姓 _____?    Y(1) ________________
2. 你係咪住喺長洲?    N(1) ________________
3. 你係咪住喺 _____?    Y(1) ________________
4. 大笨象係咪大隻過老鼠?   Y(1) ________________
5. 香蕉未剝皮之前，你會唔會食? N(1) ________________

Expression
A. Conversation:
1. 你叫咩名?    ________________
2. 你住喺邊度?    ________________
3. 你有咩病?    ________________

B. Picture Naming:
1. 杯 (1) ________________
2. 原子筆 (1) ________________
3. 睜覺 (1) ________________
4. 梳 (1) ________________
5. 拍手 (1) ________________
C. Sentence Completion:
1. 春夏秋 ___ (1) ________________
2. 洗面刷 ___ (1) ________________
3. 河水不犯 ___ (1) ________________
4. 我想飲杯 ___ (1) ________________
5. 醉翁之意不在___ (1) ________________

D. Responsive Naming:
1. 一星期有幾多日? ________________
2. 用乜嘢寫字? ________________
3. 番梘要嚟做咩? ________________
4. 護士喺邊度返工? ________________
5. 你用咩食飯? ________________

E. Verbal Fluency:
(In 1 min.; may be prompted at 30 sec.; 1 point for each animal named)
動物名稱:


F. Repetition:
1. 鑊 (1) ________________
2. 希望 (1) ________________
3. 九五折 (1) ________________
4. 時事新聞 (1) ________________
5. 去廣州探親 (1) ________________
Appendix B

Stimuli

<table>
<thead>
<tr>
<th>/si/</th>
<th>/ji/</th>
<th>/jœu/</th>
</tr>
</thead>
<tbody>
<tr>
<td>/si55/ 詩 poem</td>
<td>/ji55/ 衣 clothes</td>
<td>/jœu55/ 休 rest</td>
</tr>
<tr>
<td>/si25/ 史 history</td>
<td>/ji25/ 椅 chair</td>
<td>/jœu25/ 柚 pomelo</td>
</tr>
<tr>
<td>/si33/ 試 try</td>
<td>/ji33/ 意 meaning</td>
<td>/jœu33/ 幼 thin</td>
</tr>
<tr>
<td>/si21/ 時 time</td>
<td>/ji21/ 兒 child</td>
<td>/jœu21/ 游 swim</td>
</tr>
<tr>
<td>/si23/ 市 market</td>
<td>/ji23/ 耳 ear</td>
<td>/jœu23/ 有 have</td>
</tr>
<tr>
<td>/si22/ 是 yes</td>
<td>/ji22/ 二 two</td>
<td>/jœu22/ 又 again</td>
</tr>
</tbody>
</table>
Appendix C

Mean differences of the two measures for each variable in acoustic analysis

<table>
<thead>
<tr>
<th></th>
<th>Intra-rater</th>
<th>Inter-rater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean F0 (Hz)</td>
<td>0.063</td>
<td>0.022</td>
</tr>
<tr>
<td>SD F0 (Hz)</td>
<td>0.027</td>
<td>0.062</td>
</tr>
<tr>
<td>Intensity ratio</td>
<td>0.003</td>
<td>0.005</td>
</tr>
<tr>
<td>Duration (s)</td>
<td>0.004</td>
<td>0.011</td>
</tr>
</tbody>
</table>
Appendix D

Spectrogram showing the presence of pitch break in a statement produced by one PD speaker (with blue line showing the F0 trace)

Note: x-axis = time
       y-axis = F0
Appendix E

Consent forms

Consent Form

Intonation in Cantonese Parkinson’s disease: questions versus statements

You are invited to participate in a research study conducted by So Yee Shan, a Year 4 undergraduate in the Division of Speech & Hearing Sciences at the University of Hong Kong.

PURPOSE OF THE STUDY
The aim of this study is to investigate the production and perception of questions-statement contrasts in Cantonese individuals with Parkinson’s disease and to compare the difference in perceptual accuracy of intonation between speakers with and without Parkinson’s disease.

PROCEDURES
You will undergo two screening tests on hearing and language which will take about 15 minutes. You will also be asked to read a set of sentences in the form of a question or a statement which will take about 20 minutes. The speech samples will be audiotaped for investigation.

POTENTIAL RISKS / DISCOMFORTS AND THEIR MINIMIZATION
This study will not induce any risk or discomfort to the participants.

POTENTIAL BENEFITS
There will not be any direct benefits to individual participant. However, the study aims to provide valuable information on the effects of Parkinson’s disease on intonation.

CONFIDENTIALITY
All the data obtained from the participants will be used for research purposes only and will be kept confidential. The data will not be accessed by anyone except the investigators and you have the right to request for erasing your audio-taped data.

PARTICIPATION AND WITHDRAWAL
Your participation is voluntary. This means that you can choose to stop at any time without negative consequences and you can withdraw any unprocessed data previously supplied.

QUESTIONS AND CONCERNS
If you have any questions or concerns about the research, please feel free to contact Miss So Yee Shan at 98672830 or through email: soyeeshan@gmail.com. If you have questions about your rights as a research participant, contact the Human Research Ethics Committee for Non-Clinical Faculties, HKU (2241-5267).
SIGNATURE

I _________________________________ (Name of Participant) understand the procedures described above and agree to participate in this study.

_____________________________  ______________________________
Signature of Participant        Date

Date of Preparation: 7-12-2007
HRECNCF Approval Expiration date: 10-12-2007
Consent Form

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PROCEDURES
You will be asked to complete a listening task. Sentences or single words will be presented through headphone and you will be required to distinguish whether they come from a question or a statement by clicking a button on the computer screen. The task will take about 1 hours.

POTENTIAL RISKS / DISCOMFORTS AND THEIR MINIMIZATION
This study will not induce any risk or discomfort to you.

POTENTIAL BENEFITS
There will not be any direct benefits to individual participants. However, the study could provide valuable information on the effects of Parkinson’s disease on intonation.

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