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<th><strong>Title</strong></th>
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<tr>
<td><strong>Author(s)</strong></td>
<td>Li, Kit-ying; 李潔盈</td>
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<td><strong>Citation</strong></td>
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The Effects of Coaching and Repeated Trials
on Maximum Phonational Frequency Range in Cantonese Children

2006086783

A dissertation submitted in partial fulfilment of the requirements for the Bachelor of Science (Speech and Hearing Sciences), The University of Hong Kong, June 30, 2010
ABSTRACT

Maximum phonational frequency range (MPFR) is the frequency range from the lowest to the highest pitch that an individual can produce. This study investigated the effects of coaching and repeated trials on MPFR in Cantonese children. Thirty girls aged between 6 and 11 years were randomly assigned into two groups: coaching group and non-coaching group. All children produced their minimum and maximum phonational frequencies for 10 times each. Children in the coaching group were provided by the researcher with verbal encouragements and hand-sweeping (visual cue). Children in the non-coaching group were simply asked to repeat the tasks for 10 times. The results revealed that coaching could facilitate the elicitation of MPFR upon fewer trials. The results also showed that the MPFR elicited using 10 trials was significantly greater than that elicited in fewer trials. These findings suggested that coaching and repeated trials should be employed in clinical and research settings to ensure elicitation of MPFR more efficiently and accurately.

Key words
Maximum phonational frequency range; Coaching; Repeated trials; Cantonese children; Voice evaluation
INTRODUCTION

Maximum phonational frequency range (MPFR) refers to the frequency range from the lowest pitch in the modal register to the highest pitch in the falsetto register an individual can produce (Hollien, Dew & Philips, 1971). Glottal fry is excluded because it is not continuously used during speech production (Hollien et al., 1971).

MPFR reflects the vocal abilities of an individual (Baken & Orlikoff, 2000). It provides information about laryngeal functions during phonation (e.g., Baken & Orlikoff, 2000; Colton, Casper & Leonard, 2006). It can reflect the underlying vocal fold physiology when producing different frequencies (Colton et al., 2006). Also, it helps reveal the biomechanical and physiological limits of respiratory and phonatory systems (Reich, Mason, Frederickson & Schlauch, 1989). In addition to the individual systems, it provides information about the coordination of laryngeal, respiratory and resonatory systems in voice production (Zraick, Keyes, Montague & Keiser, 2002). Clinically, a reduced MPFR can be a primary acoustic sign of voice problems (Colton et al., 2006). Hirano et al. (1991) found the MPFR decreased in individuals with vocal pathologies, for example, vocal polyps, nodules and paralysis. Hence, MPFR can also distinguish pathological voice from normal voice by comparing against the normative data according to the individual’s age and gender (Hirano, Tanaka, Fujita & Terasawa, 1991).

Currently, there is no standardized procedure to elicit MPFR which makes the comparison of data across different voice clinics and research difficult (e.g., Reich et al., 1990; Zraick, Keyes et al., 2002; Zraick, Nelson, Montague & Monoson, 2000). Moreover, variability of MPFR was reported to be rather large (Kent, Kent, & Rosenbek, 1987). Van Oordt and Drost (1963) found that children aged 6-16 years had a MPFR varying from 1.5 octaves to 3 octaves and Reich et al. (1990) showed that the MPFR of children aged 6-13 years ranged from about 1 octave to 3.6 octaves. Several authors have suggested that
numerous variables in elicitation procedures including instructions to clients, elicitation tasks, time-of-day, coaching by the clinician, visual feedback and repeated trials can lead to the large variability of MPFR across individuals (e.g., Reich et al., 1989; Coleman, 1993; Zraick, Keyes et al., 2002; Zraick, Nelson et al., 2000).

It was suggested that maximum vocal efforts are greatly affected by one’s motivation (Kent et al., 1987). As the production of MPFR involves elicitation of an individual’s maximum performance, factors affecting one’s motivation may affect the MPFR performance. Examples of these factors include verbal encouragements and coaching provided by the clinician (Coleman, 1993; Reich et al., 1989). Coleman (1993) and Kent et al. (1987) have suggested that the presence of coaching given by the clinician may increase individual’s motivation. According to McClelland (1987), extrinsic motivation caused by the external sources, for example, encouragements and incentives given by the others, can help increase one’s self-confidence and intent to achieve the goal. Hence, it is hypothesized that a greater MPFR may be elicited with coaching. On the other hand, the lack of standardized number of trials could be another variable leading to large variability of MPFR across researches. Without a standard number of trials for elicitation of MPFR, the comparisons of MPFR across settings become inappropriate. Williams and Hodges (2004) suggested that practice is one of the factors necessary for improvement in motor performances. So, it is possible that the MPFR elicited increases with the number of repeated trials.

While there is yet standardized procedure for elicitation of MPFR, some studies have been done to investigate the effects of variables on MPFR and the minimum phonational frequency. Cooper and Yanagihara (1971) examined the influences of the time-of-day on the minimum phonational frequency in a group of vocally healthy adults (both males and females). Their results found that the minimum phonational frequency varied from one to three semitones throughout the day. Furthermore, some researches investigated the effects of
elicitation tasks on MPFR. Zraick, Keyes et al. (2002) compared the effects of two elicitation procedures, mid-basal-to-ceiling versus mid-ceiling-to-basal, on MPFR in adults and found no significant difference between the MPFR elicited by these two procedures. Reich et al. (1989) investigated the MPFR of 40 third to sixth graded children. It was shown that discrete-step gave a significantly smaller MPFR than all other four elicitation tasks (slow steps, fast steps, slow glissando and fast glissando) in children. These studies suggested that different task variables could affect the elicitation of MPFR.

Besides the above studies on the effects of elicitation tasks and time-of-day, other task variables like number of trials and coaching on MPFR are still unclear (Zraick, Nelson et al., 2000; Zraick, Keyes et al., 2002). The literature has suggested the positive effects of coaching in the form of verbal encouragement on maximum phonation time elicitation (Reich, Mason, & Polen, 1986). As the effects of coaching on other voice-related maximum performances are shown, it is hypothesized that coaching may be required to elicit MPFR by increasing children’s motivation. Therefore, in the present study, the effects of coaching on MPFR will be investigated to help determine the procedures necessary to elicit more representative values of MPFR efficiently in both clinical and research settings.

Researches have found that repeated trials of more than three trials could significantly elicit better performances in other voice-related maximum performance tasks. Coleman (1993) suggested that the range of sound pressure levels elicited was significantly with successive trials over single trial. Lewis, Casteel and McMahon (1982) have shown that more than three trials were required to elicit the maximum phonational time in children. However, the specific effects of repeated trials on MPFR are still unknown (Zraick, Nelson et al., 2000). In the present study, the effects of repeated trials on MPFR in children will be investigated.

Three trials were used commonly across researches both for children and adults currently for elicitation of MPFR (e.g., Austin & Leeper, 1975; Reich et al., 1989, 1990;
Zraick, Nelson et al., 2000; Zraick, Keyes et al., 2002). However, Hollien et al. (1971) did not set a fixed number of trials and took as many trials as possible until the researchers were satisfied. Yet, no investigation has been done to find out the number of trials required for MPFR (Zraick, Nelson et al., 2000). While Zraick, Nelson et al. also stated the number of trials can be one of the factors affecting the MPFR, the present study will investigate the optimal number of trials to elicit the maximum performances in MPFR.

In additional to the effects of variables, it is required to compare the client’s MPFR with the norm in order to interpret the MPFR results and to make diagnostic evaluation (Schuckman, 2008). However, most normative data of MPFR available in the literature are based on American English speakers (e.g., Coleman, Mabis & Hinson, 1977; Hollien et al., 1971; Reich et al., 1989, 1990; Zraick, Nelson et al., 2000). There could be race differences especially when English is a non-tonal language while Cantonese is a tonal dialect in Chinese language. In Cantonese, a change in pitch can lead to a change in lexical meaning (Bauer & Benedict, 1997). Yin (2001) showed that Native Taiwanese-Mandarin speakers produced greater MPFR than American-English speakers because the tonal aspect of a language provided daily vocal exercise for the speakers. Also, Chen (2007) supported this by showing that Native Min (a tonal dialect) speakers had a significantly greater MPFR than non-tonal language speakers including American English and Dutch. In a later study, Chen (2008) found that native Taiwanese-Mandarin speakers had a greater MFPR than other non-tonal language speakers, including English, Swedish, Dutch, Belgian and Lithuanian speakers. As a result, the MPFRs among populations speaking different languages may be different. Thus, it could not be presumed that the English data available are suitable for the Cantonese-speaking speakers. Normative data for Cantonese populations are needed to allow comparisons.

In recent years, there are some researches on MPFR in Cantonese-speaking adults (e.g., Li & Yiu, 2006; Ma & Yiu, 2006; Ma et al., 2007), but none has been reported for children.
Due to the anatomical and physiological differences in vocal tracts, children’s phonational abilities should be different when compared to those of adults (Colton et al., 2006). One obvious difference is that the laryngeal structures of children are significantly smaller than that of adults. It was reported that children at 6 years and 6 months old have vocal fold length of 8mm (Negus, 1949) while adult males have the length of at least 17mm (Mathieson, 2001). The change in configuration and position of the laryngeal structures as a child grows will affect one’s vocal abilities (Mathieson, 2001). For instances, Colton et al. (2006) stated that children have smaller, shorter and less differentiated vocal folds as well as higher and more anterior position of laryngeal position which results in higher fundamental frequency and smaller MPFR in children than adults. Van Oordt and Drost (1963) showed that children have a slightly increasing MPFR as they grow. To help distinguish between normal and pathological voice, it is necessary to compare the MPFR value of an individual with the standard value of the age- and gender-matched counterparts (Schuckman, 2008). Hence, normative data for Cantonese-speaking children is essential for diagnostic reason.

The aims of the present study were 1) to establish normative data of MPFR in Cantonese-speaking children and 2) to investigate the effects of variables including coaching and repeated trials on MPFR determination in children.

**METHOD**

**Participants**

Thirty girls between the age of 6 and 11 years (mean age=8.97 years, SD=2.00) were recruited. This upper age limit was chosen to exclude puberty voice, while the lower age limit was chosen because children at this age are expected to have adequate comprehension level and attention to follow the instructions for elicitation properly. All participants were Cantonese native speakers who 1) had normal voice quality as judged perceptually by the
researcher; 2) had not received any previous voice and singing training; 3) had normal hearing according to parent’s report; 4) had no history of voice problems; 5) had no history of severe respiratory allergies and 6) did not have any speech and language disorders or delay.

Participants in coaching and non-coaching groups had similar age, weight and height. The age, weight and height of the participants were summarized in Table 1.

Table 1. Age, weight and height of all participants in two groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (in years)</th>
<th>Weight (in kg)</th>
<th>Height (in cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coaching (N=15)</td>
<td>8.97 (2.00)</td>
<td>26.93 (6.74)</td>
<td>131.60 (13.42)</td>
</tr>
<tr>
<td>Non-coaching (N=15)</td>
<td>9.00 (1.61)</td>
<td>31.87 (8.85)</td>
<td>133.60 (12.19)</td>
</tr>
</tbody>
</table>

*Note. N = Number of participants; SD = Standard deviation*

**Equipment**

All the recordings were carried out at the Voice Research Laboratory of Division of Speech and Hearing Sciences, the University of Hong Kong. The background noise was kept below 55dBA throughout the recording, as measured by sound level meter (Quest Electronics, Model 210, Oconomowoc, WI). Swell *Real-time DSP Phonetograph* Version 2.0 (Phog 2.0, AB Nyvalla DSP, Sweden) with a Pentium III 500-MHz PC computer was used to provide real-time visual feedback during trials to augment participants’ performance and for data recording. Head-mounted condenser microphone (AKG Acoustics C420, Vienna, Austria) was used to capture participants’ vocal productions.

**Procedures**

Participants were evenly and randomly assigned either the coaching group or the non-coaching group. To elicit the maximum phonational frequency range (MPFR), glissando
was employed because it is commonly used in clinical practice (Baken & Orlikoff, 2000). Reich et al. (1989) showed glissando could elicit significantly larger MPRF than discrete-step elicitation task in children. Under this procedure, the participants were instructed to phonate /a/ at their most comfortable pitch and loudness level. Then they were asked to glide from the comfortable to the lowest/highest frequency without pausing in between each pitch. Pitch-matching procedure was not employed because it is not commonly used in clinical practice (Zraick, Nelson et al., 2000). The maximum frequency and minimum frequency were elicited for 10 trials respectively. All productions were elicited by the same researcher.

Before the data collection, children were instructed to sit directly in front of the computer screen to ensure they were facing a forward position. Head-mounted microphone was placed over participant’s head with a mouth-to-microphone distance kept at 5 cm. Standardized verbal instructions (see below) and demonstration were given by the researcher to ensure the participants could understand the tasks. Participants were allowed to practise for three times before recordings to familiarize them with the tasks (Zraick, Nelson et al, 2000). The verbal instructions were shown as below:

“Today, I would like to know how high and low pitch you can produce respectively. Now listen to the instructions and I will demonstrate to you later. Take a deep breath. Then, produce /a/ at a comfortable pitch and loudness level and go to the lowest/highest pitch without pause. You can practice before the recording starts.
For a low pitch voice, you may think of how a lion roars or a witch speaks. For the high pitch voice, think of a scream when a big mouse or someone scares you suddenly. I will demonstrate to you later. (Demonstration) You can now practice the highest/lowest pitch for three times.”
Real-time visual feedback was given for all participants when eliciting the MPFR. Swell’s (Phog version 2.0) was used to show the frequency the participant was producing on a computer screen in front of the participant. The participant was instructed to watch the line on the screen which could augment his/her performance. The instructions were given as follows:

“You should look at computer screen (Researcher pointing at the window of Phog on the screen) to see the pitch you are producing during trials. The dots are showing the pitch you are at simultaneously. When you produce an increasing pitch, the green dots will go to the right drawing a line. (Researcher pointing at the right hand side of the screen) When you produce a decreasing pitch, the green dots will go to the left drawing a line. (Researcher pointing at the left hand side of the screen). You should try to draw the line for as long as possible.”

An example of the screen was given as follows:

![Figure 1](image.png)

*Figure 1.* Capture from the computer.

Children in the coaching group were given simultaneously: 1) verbal encouragements during each trial and 2) hand-sweeping up/down during the trial from the clinician. Children
were instructed to try performing better whenever they received the coaching. Verbal encouragements provided for coaching groups were shown as follows:

‘First trial: ‘I want to know how high/low you can produce. Take a deep breathe and then say /a/ from your most comfortable pitch to the highest/lowest pitch you can produce. Remember to go as high/low as possible, Ready? Go! [the child was performing] Good! Keep going!’

From the second to tenth trial: ‘You did a good job in the previous trial. Now, I want you to do that again. See if you can produce even higher/lower. Remember to take a deep breathe and go as high/low as possible! Ready? Go! [the child was performing] Good Keep going!’

Feedback provided for the non-coaching group:

“First trial: ‘I want to see how high/low you can produce. Take a deep breathe and then say /a/ from your most comfortable pitch to the highest/lowest pitch you can produce. Ready, Go! [the child was performing] Good.’

From the second to tenth trial: ‘Okay. Now, do it again...’

Minimum phonational frequency was elicited before the maximum phonational frequency to avoid vocal fatigue (Coleman, 1993). All children repeated downward trials for 10 trials before producing upward trials for 10 trials. The whole process including screening, instructions, practice and data collection took about 30 minutes. Six children (20% of the 30 children) underwent the same procedure in a month after the first data collection. This was to evaluate the test-retest reliability and agreement of the children’s performance.

Data analysis

Analysis of both minimum and maximum frequencies was done by locating the left and right
boundaries of the phonetogram with a mouse cursor on the computer screen. The lowest
frequency across the 10 trials was regarded as the minimum phonational frequency and
highest frequency across the 10 trials was regarded as the maximum phonational frequency
for each participant. The maximum phonational frequency range (MFPR) was calculated as
the difference between the maximum phonation frequency and the minimum phonational
frequency. As the analysis of fundamental frequency values presenting in Hertz is in linear
scale but perception of sounds is logarithmic, the frequency range data were converted to
logarithmic scale in semitones. This provides a standard comparison across coaching and
non-coaching groups (Ma et al., 2007). The conversion of frequency range from the unit of
Hertz to the unit of semitones was done by using the algorithm below:

\[
\text{MPFR in semitones} = \frac{\log_{10}\left(\text{The highest frequency in Hertz} \div \text{The lowest frequency in Hertz}\right)}{\log_{10}2} \times 12
\]

To summarize, four dependent measures were derived from each child. They included 1)
maximum phonational frequency in Hertz; 2) minimum phonational frequency in Hertz and 3)
MFPR in Hertz and 4) MPFR in semitones.

Reliability of data analysis

As the determination of the frequency measures require visual judgment of frequency data
(minimum and maximum frequencies) from the computer screen, the reliability of this
procedure needed to be established. The voice recordings of three children in each group (6
children in total comprising 20% of total 30 participants) were re-analyzed by the researcher.
This was to evaluate the intra-rater reliability. The same recordings of these 6 children were
analyzed by another student clinician. This was to evaluate the inter-rater reliability. These
two reliabilities were evaluated by Pearson’s correlation \( r \).

RESULTS
Reliability of data analysis

Correlational analysis using Pearson’s $r$ reviewed very high intra-rater reliability in minimum and maximum frequencies and inter-rater reliability in maximum frequency. Also, high inter-rater reliability in minimum frequency and test-retest reliability were found in both frequency measures. Table 2 lists the results of test-retest, inter-rater and intra-rater reliabilities and agreement in minimum and maximum frequencies.

Table 2. Test-retest, inter-rater and intra-rater reliabilities and agreement in minimum and maximum frequencies

<table>
<thead>
<tr>
<th></th>
<th>Pearson’s $r$</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Exact agreement</td>
</tr>
<tr>
<td><strong>Minimum Frequency</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intra-rater</td>
<td>.962*</td>
<td>81.7</td>
</tr>
<tr>
<td>Inter-rater</td>
<td>.811*</td>
<td>53.3</td>
</tr>
<tr>
<td>Test-retest</td>
<td>.824*</td>
<td>26.7</td>
</tr>
<tr>
<td><strong>Maximum Frequency</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intra-rater</td>
<td>.998*</td>
<td>91.7</td>
</tr>
<tr>
<td>Inter-rater</td>
<td>.974*</td>
<td>66.7</td>
</tr>
<tr>
<td>Test-retest</td>
<td>.800*</td>
<td>13.3</td>
</tr>
</tbody>
</table>

*Significance level at .0001

Note. ST = semitone; *Significance level at .0001

MPFR across trials

Table 3 lists the means and standard deviations of the four frequency measures in coaching group and non-coaching group across the 10 trials. Figures 2, 3 and 4 visualize the trend of minimum frequency, maximum frequency and MPFR in Hertz across 10 trials.
Table 3. Means (and standard deviations) for 4 frequency-related measures across ten trials in coaching and non-coaching groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of trials</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Minimum frequency in Hertz</strong></td>
<td></td>
</tr>
<tr>
<td>Pooled data</td>
<td>177.67</td>
</tr>
<tr>
<td>C</td>
<td>171.05</td>
</tr>
<tr>
<td></td>
<td>(34.81)</td>
</tr>
<tr>
<td>NC</td>
<td>184.29</td>
</tr>
<tr>
<td><strong>Maximum frequency in Hertz</strong></td>
<td></td>
</tr>
<tr>
<td>Pooled data</td>
<td>1686.65</td>
</tr>
<tr>
<td>C</td>
<td>1786.45</td>
</tr>
<tr>
<td></td>
<td>(723.40)</td>
</tr>
<tr>
<td>NC</td>
<td>1586.85</td>
</tr>
<tr>
<td></td>
<td>(624.59)</td>
</tr>
<tr>
<td><strong>Frequency range in Hertz</strong></td>
<td></td>
</tr>
<tr>
<td>Pooled data</td>
<td>1508.98</td>
</tr>
<tr>
<td>C</td>
<td>1615.39</td>
</tr>
<tr>
<td></td>
<td>(739.69)</td>
</tr>
<tr>
<td>NC</td>
<td>1402.56</td>
</tr>
<tr>
<td></td>
<td>(644.11)</td>
</tr>
<tr>
<td><strong>Frequency range in semitones</strong></td>
<td></td>
</tr>
<tr>
<td>Pooled data</td>
<td>37.80</td>
</tr>
<tr>
<td></td>
<td>(10.76)</td>
</tr>
<tr>
<td>NC</td>
<td>36.46</td>
</tr>
<tr>
<td></td>
<td>(9.38)</td>
</tr>
</tbody>
</table>

*Note. C = Coaching; NC = Non-Coaching; Standard deviations are in parentheses.*
Figure 2. Mean minimum frequency across ten trials in coaching and non-coaching groups

Figure 3. Mean maximum frequency across ten trials in coaching and non-coaching groups

Figure 4. Mean MPFR (in Hertz) across ten trials in coaching and non-coaching groups
**Effects of coaching on MPFR**

Table 4 lists the means (standard deviations) and the ranges of four frequency measures across 10 trials for coaching and non-coaching groups. The mean MPFR for coaching group was 48.3 ST (SD=5.7) and the mean MPFR for non-coaching group was 42.9 ST (SD=9.0).

Independent t-test was used to analyze the minimum frequency (Hz), maximum frequency (Hz) and MPFR (Hz and ST) to investigate the effects of coaching. Since four repeated t-tests were carried out for data analysis, the *alpha* level was adjusted to 0.0125 (0.05/4) using Bonferroni adjustment to avoid any potential Type I errors. No statistically significance was shown in all frequency measures between the two groups. Results of the t-test result are listed in Table 4.

**Table 4. Means (standard deviations) and ranges of the four frequency measures across 10 trials in coaching group and non-coaching group**

<table>
<thead>
<tr>
<th>Measures (unit)</th>
<th>Coaching</th>
<th>Non-coaching</th>
<th>Independent t Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Range</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Minimum</td>
<td>135.18 (26.20)</td>
<td>103.8-196.0</td>
<td>151.79 (29.22)</td>
</tr>
<tr>
<td>F₀ (Hz)</td>
<td>2341.85 (636.48)</td>
<td>1179.7-3520</td>
<td>1905.85 (758.23)</td>
</tr>
<tr>
<td>Maximum</td>
<td>2206.67 (630.24)</td>
<td>1074.7-3396.5</td>
<td>1754.06 (765.18)</td>
</tr>
<tr>
<td>MPFR (Hz)</td>
<td>48.99 (5.84)</td>
<td>35.0-58.0</td>
<td>42.73 (8.83)</td>
</tr>
</tbody>
</table>

*Note.* Standard deviations are in parentheses.
Effects of repeated trials

Table 5 lists the means and standard deviations of the minimum frequency (Hz), maximum frequency (Hz) and MPFR (Hz/ST) upon the first trial, three trials, five trials and ten trials. In order to investigate the main effects of repeated trials and interaction effects of coaching and repeated trials, two-way mixed ANOVA (trials × group) was employed with group as between-subject factor (coaching versus non-coaching) and number of trials (1 versus 3 versus 5 versus 10 trials) as within-subject factor for each measure. Mauchly’s test of sphericity for within-subject factor was significant (p=.0001). This indicated that the assumption of compound symmetry was violated. Therefore, results of within-subject effects with Greenhouse-Geisser epsilon correction, which corrected the degree of freedom, were reported.

Main effects of trials. Significant main effects of trials were found for minimum phonational frequency (Hz) \((F(1,3)=18.60, p=.0001)\); maximum phonational frequency (Hz) \((F(1,3)=14.67, p=0.001)\), MPFR in Hertz \((F(1,2)=17.51, p=.0001)\) and MPFR in semitone \((F(1,2)=28.71, p=.0001)\) among the four numbers of trials. Follow-up repeated one-way ANOVA was performed within each measure to further evaluate the main effect of repeated trials. For these analyses, Bonferroni correction was introduced to avoid any potential Type I errors (Ma & Love, 2010). In all frequency measures (Min F\(_0\) in Hz, Max F\(_0\) in Hz, MPFR in Hz & ST), the measures elicited in 10 trials were significantly better than in the first trial and in three trials (all \(p<.01\)). That is, the minimum frequencies elicited in ten trials were significantly lower than while the maximum frequencies were significantly higher in ten trials; and the MPFRs were significantly greater in 10 trials. All frequency measures elicited from three and five trials were similar (all \(p>.05\)) except for the MPFR in semitones (\(p=.005\)).

Main effects of group. No group main effect was revealed for all measures.

Interaction effects. None of the interactions reached significant level.
Table 5. *Means and standard deviations for the minimum frequency (Hz), maximum frequency (Hz), MPFR (Hz/ST) upon first trial, 3 trials, 5 trials and 10 trials across coaching and non-coaching groups*

<table>
<thead>
<tr>
<th>Number of trials</th>
<th>Group</th>
<th>Measures</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min $F_0$</td>
<td>Max $F_0$</td>
<td>MPFR</td>
<td>MPFR</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Hz)</td>
<td>(Hz)</td>
<td>(Hz)</td>
<td>(Hz)</td>
<td>(ST)</td>
</tr>
<tr>
<td>First trial</td>
<td>Pooled data</td>
<td>177.67</td>
<td>1686.65</td>
<td>1508.98</td>
<td>37.80</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>171.05</td>
<td>1786.45</td>
<td>1615.39</td>
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<td></td>
<td>(34.81)</td>
<td>(723.40)</td>
<td>(739.69)</td>
<td>(10.76)</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td>(45.39)</td>
<td>(624.59)</td>
<td>(644.11)</td>
<td>(9.38)</td>
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</tr>
<tr>
<td>3 trials</td>
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<td>157.49</td>
<td>1872.82</td>
<td>1715.33</td>
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<td></td>
<td>C</td>
<td>145.01</td>
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<td></td>
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<td>(699.60)</td>
<td>(700.36)</td>
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<td></td>
<td>(32.83)</td>
<td>(700.92)</td>
<td>(705.45)</td>
<td>(8.59)</td>
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<td>(29.23)</td>
<td>(758.2)</td>
<td>(765.18)</td>
<td>(9.82)</td>
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*Note.* C = Coaching; NC = Non-Coaching; Standard deviations are in parentheses.

Minimum number of trials required to elicit maximum performances

Cumulative frequency distribution graphs (Figures 5a, b and c) were plotted to show the
number of trials required to elicit minimum and maximum frequencies and MPFR, respectively, in all participants. For the minimum frequency (see Figure 5a), 80% of participants in coaching group could achieve their lowest frequency in three trials while nine trials were required in non-coaching group. For the maximum frequency (see Figure 5b), 80% of participants in coaching group could achieve their highest frequency in six trials while nine trials were required in non-coaching groups. For the MPFR (see Figure 5c), seven and ten trials were required for at least 80% of participants to achieve their highest frequency in coaching and non-coaching groups respectively.

Figure 5a. Percentage of participants reaching minimum frequency for each of 10 trials in each group.

Figure 5b. Percentage of participants reaching maximum frequency for each of 10 trials in
each group.

![Graph showing percentage of participants reaching MPFR for each of 10 trials in each group.]

**Figure 5c.** Percentage of participants reaching MPFR for each of 10 trials in each group.

**DISCUSSION**

The aims of the present study were 1) to establish normative data of MPFR in Cantonese-speaking children and 2) to investigate the effects of variables including coaching and repeated trials on determining MPFR in children. In this study, maximum and minimum frequencies in girls with normal voice quality were elicited using glissando. The results revealed no significant coaching effect on values of minimum frequency, maximum frequency and MPFR. However, all frequency measures could be achieved in smaller number of trials in the coaching group than the non-coaching group. In addition, the MPFRs elicited in the first trial, the first three and five trials were significantly smaller than that in ten trials in both groups.

**Comparison with the literature on MPFR in children**

The mean MPFR (coaching group: 48.99 ST; non-coaching group: 42.73 ST) found in this study was greater than the available established values of frequency range (e.g., Reich et al., 1989; McAllister, Sederholm, Sundberg & Gramming, 1994). As most of the previous studies
used 3 trials instead of 10 trials, the MPFR elicited in 3 trials may be used for the comparison. Considering the use of 3 trials, the mean MPFRs obtained from the present study (coaching: 44.99 ST; non-coaching: 39.0 ST) were still larger than those reported in the literature. Reich et al. (1989), for example, found the MPFR mean of 28.35 ST (collapsed across gender) in three trials. The elicitation task (glissando) used was very similar to this study. However, boys were included and pitch-matching procedure was employed in that research, so it is difficult to compare the MPFR values with this study.

McAllister et al. (1994) showed non-dysphonic children (aged 10 years old) had a mean frequency range of 24 ST. Heylen and colleagues (1998) found the non-dysphonic children aged between 6 and 11 years could produce a MPFR of 26.4 ST. In these two studies, pitch-matching was employed while detail was not given on the procedures like whether coaching was given or the number of trials used, these variables make comparisons not appropriate. Nevertheless, the great differences in MPFR values with different procedures may suggest the necessity of a standardized elicitation method for fair comparisons in clinical and research settings. Clinically, it is important to ensure valid comparisons with a norm in voice evaluation. This may also imply that the effects of different variables should be investigated to help establish the standardized method.

**Effects of coaching on eliciting MPFR**

In this study, all the frequency measures (the minimum frequency, maximum frequency and MPFR) were similar between the coaching and non-coaching groups. This suggested that there was no clear coaching effect on the maximum vocal performance. The results are not consistent with the findings showing the significant coaching effect on other maximum vocal performance tasks such as maximum phonation time (Reich et al., 1986) and maximum sound pressure level (Coleman et al., 1977).
The present results might possibly be due to the provision of visual feedback during elicitation. Visual feedback may have contributed to the insignificant difference in MPFR found between coaching and non-coaching groups. Firstly, it was proposed that feedback can increase one’s motivation to achieve the goal as well as the motivation to learn, hence this enhances performance in voice range profile (Coleman, 1993; Zelaznik, 1996). McClelland (1987) mentioned that being provided with information from the task can help increase one’s intrinsic motivation. During the task, the voice range profile visualized a child’s simultaneous performance. This could have encouraged the children to perform better because they might feel interested and pleased to view their real-time performance and their improvement. Since the production of MPFR involves elicitation of maximum performance, it can be dependent on one’s motivation (Kent et al., 1987). In other words, it was possible that the maximal performance could be elicited despite no coaching with the provision of visual feedback. Thus, there was no significant increase in MPFR in the coaching group than the non-coaching one.

In additional to intrinsic motivation, visual feedback could assist children’s learning simultaneously during the task. This might have explained the insignificant coaching effect. Verdolini and Lee (2004) suggested that visual feedback can help improve performance in speech production tasks. They stated that augmented feedback can help individual process information in speech production skills and hence improve learning. Also, Zelaznik (1996) stated that any real-time feedback, including visual feedback, can facilitate performance. Researches have shown consistent results too, for instances, Finnegan (1984) has found that the presence of visual feedback allowing self-monitor for practice could significantly increase maximum phonation time in children. As a result, the children in non-coaching group could achieve their maximal performance with visual feedback though no coaching was given.

Although no coaching effect was found on the all frequency measures (Min $F_0$, max $F_0$ and MPFR), the results revealed that coaching could facilitate the elicitation of MPFR with
fewer trials. One possible explanation is that coaching can increase the children’s motivation to perform better. Coleman (1993) mentioned that the elicitation of vocal performances could be related to whether an investigator was able to motivate the participant. Encouragements and incentives may increase extrinsic motivation as they may help increase one’s self-confidence and intent to achieve a goal (McClelland, 1987). As verbal encouragements were given after each trial while hand-sweeping and verbal remainder were provided during trials in the coaching group, these might serve as the extrinsic sources to arouse the participants’ motivation. The children could feel more confident and motivated to perform with the presence of researcher’s coaching and encouragements. This could lead to the sooner elicitation of the best performances in coaching group than non-coaching one.

**Effects of repeated trials on MPFR**

The results in this present study showed that the frequency measures elicited in the first trial were significantly poorer than subsequent trials regardless of groups. Children could not reach their MPFR in the first single trial in non-coaching group. Although coaching was found to facilitate the elicitation, only 20% of children could reach MPFR by the first single trial. This showed that repeated trials are crucial to elicit MPFR in children. The MPFR elicited in 10 trials were significantly greater than in the first trial, three and five trials. The results were consistent with the previous findings on other voice-related tasks maximum phonation time (Finnegan, 1984; Lewis et al., 1982).

The effects of repeated trials could be related to practice effect on maximal performances. Bless and Hirano (1982) suggested that the best performances can be elicited only when sufficient practices were allowed. Coleman (1993) further supported this stating that maximum performances in phonetogram were obtained when the participants were familiar with the task. It is evident that repeated practices can increase one’s familiarity with a
task (Boyle & Ackerman, 2004). So, repeated trials allowed the children to practise repeatedly until they are familiar with the methods and procedures in order to elicit their maximal vocal efforts. Thus, repeated trials were important to elicit MPFR.

**Minimum number of trials required to elicit MPFR**

In this study, it was found that MPFR could not be elicited in three trials in coaching and non-coaching groups. This implied the common procedure using three trials in most researches in children (e.g., Austin & Leeper, 1975; Reich et al., 1989; Van Oordt & Drost, 1963) was not sufficient. Eighty percent of participants required seven trials and ten trials to reach their MPFR in coaching and non-coaching group respectively. This study suggested a radical rethink of the use of only three trials to obtain MPFR in children for both research and clinical reasons. It is important to ensure the MPFR values elicited are the true maximum vocal efforts of the children. Otherwise, the vocal abilities of children may be underestimated.

On the whole, it was revealed that the minimum of trials to elicit frequency-related maximum performances depended on whether coaching was given. For the minimum frequency, about three trials were required with coaching but about nine trials were needed without coaching while about six trials and nine trials, respectively, were required in coaching and non-coaching groups to reach their maximum frequency (80% criterion). These discrepancies between coaching and non-coaching groups provided evidence that it is critical to determine the minimum number of trials according to the procedures used in a particular study.

**LIMITATIONS AND FUTURE RESEARCH**

Caution should be taken in generalizing these findings to the wider children population due to the relatively small number of vocally healthy girls in the present study. A more representative
sample can enhance the generalizability of the present results. This helps establish normative data in Cantonese children. For example, future study can include boys to find out if there is interaction across gender, coaching, repeated trials effects because the personality of boys and girls may be different which may affect their motivation to perform the task. This study included non-dysphonic girls only for the effects of variables could be isolated without gender effect. It was suggested that dysphonic voice would increase the variability and hence reduce the precision of investigation (Reich et al., 1986). Since it was proposed that the MPFR could be used to discriminate dysphonic children from normal ones, dysphonic children should be included in the future studies. This can help develop comprehensive normative data for diagnostic reasons.

As suggested by Zraick, Nelson et al. (2000), there are more variables like task instructions, provision of pitch-matching procedures, which can possibly affect MFPR. So, research can be done to investigate the effects of these factors to help standardize the procedures for the elicitation of MPFR. This allows the comparison across studies and clinics possible.

**CONCLUSIONS AND CLINICAL IMPLICATIONS**

In this study, the MPFR elicited allowed the establishment of preliminary normative data of MPFR in Cantonese-speaking non-dysphonic girls aged between 6 and 11 in Hong Kong. Also, the results of this study showed that coaching has no effect on values of minimum frequency, maximum frequency and MPFR. However, coaching allows the MPFR to be elicited more efficiently with fewer trials. Furthermore, while 3 trials are commonly used in most clinical and research settings currently, this study showed that this procedure could be reviewed. Despite coaching could facilitate the elicitation, the minimum number of trials required was shown to be about 7 trials compared to 10 trials if no coaching was given.
according to this present study. This suggests that repeated trials of more than commonly-used three trials are necessary to elicit the MPFR in children.

It was found that the two variables, including coaching and repeated trials, had significant effects on elicitation of MPFR. So, it is recommended that coaching and repeated trials of seven trials may be included to elicit MPFR as soon as possible with time constraint in clinical settings. Also, standard number of trials should be established to standardize the elicitation procedures. This can allow the establishment of more reliable and representative normative data and hence to allow comparisons of data across clinical settings and research settings. This can be important for diagnostic evaluation.
REFERENCES


APPENDIX

Appendix A

Screening Forms

Questionnaire on medical history (English version)

Name: __________________ Sex: M / F
Date of Birth: ____________ Telephone No.: ____________

1. Do you have a voice problem? (e.g. vocal nodules, aphonia, laryngitis, hoarseness)
   □ Yes, please specify: ____________________________
   when? ____________________________
   □ No

2. Have you ever had a voice problem?
   □ Yes, please specify: ____________________________
   when? ____________________________
   □ No

3. Have you ever had surgery on your larynx?
   □ Yes
   □ No

4. Have you ever received vocal training?
   □ Yes
   □ No

5. Do you have the following problems?
   □ Hearing loss
   □ Speech disorder
   □ Language disorder
   □ Upper respiratory tract infection
   □ Nasal allergy
   □ Asthma
有關病歷的問卷（中文版本）
姓名：________________ 性別：男 / 女
出生日期：____________ 電話號碼：____________

1. 你現在是否患有聲線問題（例如：瘜肉、失聲、喉嚨發炎、聲音沙啞）？
   □ 是，請說明：_________________________
   a. 甚麼時候開始有聲線問題？ ______________
   b. 是否就聲線問題接受耳鼻喉科醫生評估/治療？
      i. 何時：____________
      ii. 診斷結果：____________
   c. 你有否就聲線問題服藥 / 接受任何形式治療？
      治療形式：____________________
   □ 否

2. 那你是否曾經患有聲線問題？
   □ 是，何時？並請說明：_____________________
   □ 否

3. 你的喉嚨有沒有曾經做過手術？
   □ 有
   □ 沒有

4. 你有沒有受過聲樂 / 歌唱訓練？
   □ 有
   □ 沒有

5. 你有沒有以下的問題呢？
   □ 聽障
   □ 言語障礙
   □ 語言障礙
   □ 上呼吸道系統感染（例如：感冒、傷風）
   □ 鼻敏感
   □ 哮喘
Appendix B

Verbal encouragements provided for coaching groups (English version)

‘First trial: ‘I want to know how high/low you can produce. Take a deep breathe and then say /a/ from your most comfortable pitch to the highest/lowest pitch you can produce. Remember to go as high/low as possible, Ready? Go! [participant was performing] Good! Keep going! Good!’

From the second to tenth trial: ‘You did a good job in the previous trial. Now, I want you to do that again. See if you can produce even higher/lower. Remember to take a deep breathe and go as high/low as possible! Ready? Go! [participant was performing] Good Keep going!

Feedback provided for the non-coaching group:

“First trial: ‘I want to see how high/low you can produce. Take a deep breathe and then say /a/ from your most comfortable pitch to the highest/lowest pitch you can produce. Ready, Go! [participant was performing] Good.

From the second to tenth trial: ‘Okay. Now, do it again. ’

口頭提示 – 有指導/提示組

第一次嘗試: ‘我想知道你可以講到幾高/低音喎。 深呼吸, 吸啖大氣, 然後講‘啊’, ‘啊’到最高/低音為止// 高音 d, 再高音 d… 好叻喎/做得好好喎!’

第二至十次嘗試: ‘好啦, 再嚟一次!’ 今次要再高/低音 d 喺! 記住深呼吸, 吸啖大氣, 然後講‘啊’，要‘啊’到最高/低音為止// 高/低音 d, 再高/低音 d… 好叻喎

口頭提示 – 沒有指導/提示組

第一次嘗試: ‘我想知道你可以講到幾高/低音喎。 深呼吸, 吸啖大氣, 由你平時講野喺個

第二至十次嘗試: ‘好啦, 再嚟一次!’ 記住深呼吸, 吸啖大氣, 然後要‘啊’到最高/低音為止...好!’
Appendix C

Instructions (English version)

Today, I would like to know how high and low pitch you can produce respectively. Now listen to the instructions and I will demonstrate to you later. Take a deep breath. Then, produce /a/ at a comfortable pitch and loudness level and go to the lowest/highest pitch without pause. You can have practice before the recording start.

For a low pitch voice, you may think of how a lion roars or how a witch speaks. For the high pitch voice, think of a scream when a big mouse or someone scares you suddenly. I will demonstrate to you later. (Demonstration) You can now practice the highest/lowest pitch for three times.

一般指示 (所有參加者)

深呼吸，吸啖大氣，然後講“啊”，由你平時講野嘅音開始“啊” (研究員示範)。你一陣間可以練習下先開始。

一陣間你試低音，好似獅子叫“嘩”嘅音低音 或者好似巫婆咁低音。然後試高音嘅，好似你平時玩突然有人嚇你或者見到宅老鼠尖叫。我一陣會試範比你聽 (研究員試範) 你依家可以練習高音/低音三次
Appendix D

Instructions for Visual feedback

“You should look at computer screen (Clinician pointing the window of Phog on the computer screen) to see the pitch you are producing during trials. The dots are showing the pitch you are at simultaneously. When you produce an increasing pitch, the green dots will go to the right drawing a line. (Clinician pointing at the right hand side of the screen) When you produce a decreasing pitch, the green dots will go to the left drawing a line. (Clinician pointing at the left hand side of the screen). You should try to draw the line for as long as possible.”

視覺回應指引

望下電腦呢度，有條線喎[研究員指著螢光幕]，你越高/低音，右/左邊呢條線呢條線會越長喎。你幫姐姐整一條最長嘅線。
Appendix E

PARENT/GUARDIAN CONSENT FORM

Maximum phonational frequency range in Cantonese children

Your child is invited to participate in a research on maximum phonational frequency range (MPFR) conducted by a Year 4 student, Trista Li, from the Division of Speech & Hearing Sciences at the University of Hong Kong.

PURPOSE OF THE STUDY

This project aims at finding out the maximum phonational frequency range in Cantonese speaking children. Another aim is to investigate which eliciting procedures can result in more reliable MPFR data.

PROCEDURES

All participants will be instructed to produce their lowest pitch and highest pitch for 10 trials respectively. Participants will phonate /a/ from the most comfortable pitch and to the lowest note one can produce. Downward trials will be repeated for 10 times. After that, participants will be instructed to phonate /a/ from one’s most comfortable pitch and to the highest note one can produce. Upward trials will be repeated for 10 times.

All data will be collected at the Voice Research Laboratory of Division of Speech and Hearing Sciences, The University of Hong Kong. The whole procedure will take about 30 minutes.

POTENTIAL RISKS/DISCOMFORTS AND THEIR MINIMIZATION

There is no direct benefit for the participants. However, the research project can provide valuable information for voice assessment for children.
CONFIDENTIALITY

Any information obtained in this study will remain strictly confidential, will not be disclosed to any other people and will be used for research purposes only. Codes, not names, are used on all test instruments and subject files to protect confidentiality. Participant will not be identified by name in any report of completed study.

STORAGE OF DATA

For research purposes, your child’s participation will be digitally recorded and audio-taped for further data checking. The data will be transcribed into archives with all personal identifies removed and kept indefinitely. They will be stored in a locked cabinet in the office of Division of Speech and Hearing Sciences, The University of Hong Kong. Only the research team will have access to the data.

PARTICIPATION AND WITHDRAWAL

Your child’s participation in this project is voluntary. This means that your child can withdraw from this project at any stage, for any reasons, without negative consequences. We will erase the entire information obtained, or parts of it if you want us to do so.

QUESTIONS AND CONCERNS

You will be asked to complete and sign the consent form on the opposite page. Please feel free to ask any question about the research now. If you would like to ask any further questions, please contact the student investigator Trista Li (Tel: 61866221; email: tristali@hkusua.hku.hk) or supervisor of this research, Dr. Estella Ma from the Division of Speech and Hearing Sciences, The University of Hong Kong (Tel: 28590594; email: estella.ma@hku.hk). If you want to know more about the rights as a research participant, please contact the Human Research Ethics Committee for Non-Clinical Faculties, the University of Hong Kong (Tel: 2241-2567).

Thanks you very much for your interest and support.
本人 ______________________ (父母或監護人姓名) 已經有足夠機會詢問清楚有關這項研究的內容，並同意子女 ______________________ (參加者姓名) 參加這項研究。

I ______________________ (Name parent/guardian) have been given the opportunity to ask questions about this study and they have been answered to my satisfaction. I understood the procedures described above and agree to allow my child ______________________ (Name of participant) to participate in this study.

聯絡電話: ______________________
Contact no. ______________________

參加者父母或監護人姓名 (正楷) Subject’s guardians’/parent’s name (Block letter)
參加者父母或監護人簽署 Subject’s guardians’/parent’s signature

見證人姓名 (正楷) Witness’s name (Block letter)
見證人簽署 Witness’s signature

日期 Date

本同意書制定日期: 2009 年 11 月 19 日
Date of preparation: 19th November, 2009
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