

RELIABILITY OF ACOUSTIC PARAMETERS
MEASUREMENT FROM DIFFERENT TRIALS OF
VOICE SAMPLE PRODUCTION

by

THONG WAI SENG

Dissertation submitted in partial fulfillment of
the requirements for the degree of
Bachelor of Health Sciences (Speech Pathology)

May 2015

ACKNOWLEDGEMENT

First and foremost, I would like to express my utmost gratitude to Mr. Khairy Anuar Mohd Khairuddin, firstly, for being an exemplary academic supervisor and specifically, for being an enthusiastic and patient thesis supervisor in providing mentorship, guidance, encouragement and comprehensive feedback one could imagine throughout the process in completing this research project.

I would also like to extend my countless gratitude to Dr. Kueh Yee Cheng and Dr. Wan Nor Arifin for the invaluable advice, guidance and input on the statistical analysis. In addition, my sincere thanks also go to the staffs in Klinik Pertuturan Bahasa, in assisting me on the instruments for the data collection. Thanks a lot to all the participants who were willing to participate in this research despite their tight schedule. Without this, my work would have been impossible.

Last but not least, I would like to extend my love and appreciation to my family members for their unconditional love, encouragement and support. I would also like to thank all my friends who always gave a great support and encouragement to me along the journey.

TABLE OF CONTENTS

DECLARATION	ii
CERTIFICATE	iii
ACKNOWLEDGEMENT	iv
TABLE OF CONTENT	v
LIST OF TABLES	viii
LIST OF FIGURES	x
LIST OF SYMBOLS	xi
LIST OF ABBREVIATIONS	xii
ABSTRAK	xiii
ABSTRACT	xiv
CHAPTER 1: INTRODUCTION	1
1.1 Problem statement	2
1.2 Study objectives	2
1.2.1 General	2
1.2.2 Specific	3
1.3 Research questions	3
CHAPTER 2: LITERATURE REVIEW	4
2.1 Acoustic voice analysis	4
2.2 Acoustic parameters	4
2.3 Reliability of acoustic parameters measurement	7
2.4 Number of voice sample production trials to get reliable acoustic parameters measurement	7

2.5 Intraclass correlation coefficients	8
---	---

CHAPTER 3: METHODOLOGY.....9

3.1 Study design	9
3.2 Instruments	11
3.3 Voice sample	11
3.4 Voice recording procedures	12
3.5 Participants	12
3.6 Data collection	14
3.6.1 Procedures	14
3.7 Data analysis	15
3.8 Statistical analysis	15

CHAPTER 4: RESULTS 17

4.1 Introduction	17
4.2 Participant demographics	17
4.3 Summary of the mean, standard deviation and ranges values for the acoustic parameters according to voice production trials	18
4.3.1 Fundamental frequency	18
4.3.2 Jitter percent	19
4.3.3 Shimmer percent	19
4.3.4 Harmonic-to-noise ratio	20
4.4 The ICCs values of each acoustic parameters over the trials.....	21
4.4.1 Fundamental frequency	21
4.4.2 Jitter percent	22

4.4.3 Shimmer percent	23
4.4.4 Harmonic-to-noise ratio	24
4.5 Number of voice sample trials required to achieve reliable measurement of acoustic parameters	25
CHAPTER 5: DISCUSSIONS	26
5.1 Introduction	26
5.2 Demography characteristics of the participants	26
5.3 Number of trials required to obtain reliable measurement of acoustic parameter.....	27
5.4 Limitation and recommendations	29
CHAPTER 6: CONCLUSION	31
REFERENCES	32
APPENDICES.....	41
Appendix A – Ethics approval letter	42
Appendix B – Medical and voice history questionnaire	45
Appendix C – Voice screening form	46
Appendix D – Grandfather passage	47
Appendix E – Project information sheet (Malay version)	48
Appendix F – Project information sheet (English version)	51
Appendix G – Consent form (Malay version)	54
Appendix H – Consent form (English version)	55

LIST OF TABLES

Table 2.1

The normative data of the acoustic parameters in males 6

Table 2.2

The normative data of the acoustic parameters in females 6

Table 2.3

Number of trials required for obtaining reliable acoustic parameters measurement.....8

Table 4.1

Participant demographics 17

Table 4.2

Mean, standard deviation and range values for fundamental frequency 18

Table 4.3

Mean, standard deviation and range values for jitter percent 19

Table 4.4

Mean, standard deviation and range values for shimmer percent 20

Table 4.5

Mean, standard deviation and range values for harmonic-to-noise ratio	20
---	----

Table 4.6

The ICC values of voice sample production trials for fundamental frequency	21
--	----

Table 4.7

The ICC values of voice sample production trials for jitter percent	22
---	----

Table 4.8

The ICC values of voice sample production trials for shimmer percent	23
--	----

Table 4.9

The ICC values of voice sample production trials for harmonic-to-noise ratio	24
--	----

Table 4.10

Summary of the number of the trials required to obtain consistent production for acoustic parameters of voice	25
---	----

LIST OF FIGURES

Figure 1: The study design	10
----------------------------------	----

LIST OF SYMBOLS

%	Percentage
cm	Centimeter
dB	Decibel
Hz	Hertz
N	Number

LIST OF ABBREVIATIONS

MDVP	Multi Dimensional Voice Program
ICCs	Intraclass correlation coefficients
USM	Universiti Sains Malaysia
USMKK	Universiti Sains Malaysia Kampus Kesihatan
KPB	Klinik Pertuturan Bahasa
PPSK	Pusat Pengajian Sains Kesihatan
SLP	Speech-language pathologist
SLM	Sound level meter
SPSS	Statistical Program for Social Science
SD	Standard deviation

ABSTRAK

Kajian ini bertujuan untuk mengkaji bilangan cubaan penghasilan sampel suara yang diperlukan untuk memperolehi pengukuran dipercayai dalam ciri-ciri akustik suara, iaitu frekuensi asas, peratusan *jitter*, peratusan *shimmer* dan nisbah *harmonic-to-noise ratio*. Berdasarkan pensampelan mudah, sebanyak 33 orang lelaki telah direkrut dalam kajian ini. Semua peserta diminta untuk menghasilkan /a/ dengan kenyaringan dan kelangsingan suara yang biasa sekurang-kurangnya 5 saat untuk 15 percubaan. Sampel suara telah dianalisis secara objektif untuk mendapatkan ciri-ciri akustik suara. Nilai *Intraclass Correlation Coefficients* (ICCs) untuk 3 hingga 15 cubaan bagi setiap ciri-ciri akustik suara diukur untuk menentukan bilangan cubaan penghasilan sampel suara yang menghasilkan pengukuran ciri-ciri akustik yang boleh dipercayai.

Keputusan untuk kajian ini menunjukkan tiga cubaan penghasilan suara diperlukan untuk memperolehi kedua-dua penghasilan sampel suara yang boleh diterima dan cemerlang bagi tiga ciri-ciri akustik suara, iaitu frekuensi asas, peratusan *shimmer* dan nisbah *harmonic-to-noise ratio*. Bagi peratusan *jitter*, sekurang-kurangnya empat cubaan penghasilan sampel suara diperlukan untuk memperolehi pengukuran yang boleh diterima, manakala sekurang-kurangnya tujuh cubaan penghasilan sampel suara bagi pengukuran yang cemerlang. Menurut kajian ini, minimum empat cubaan penghasilan sampel suara dicadangkan untuk memperolehi pengukuran yang boleh diterima bagi setiap ciri-ciri akustik suara.

ABSTRACT

The present study aims to investigate the number of voice sample production trials required to obtain reliable measurement of acoustic parameters i.e., fundamental frequency, jitter percent, shimmer percent, and harmonic-to-noise ratio. Based on a convenient sampling, a total of 33 males participants were recruited in the present study. Each participant was required to produce sustained vowel /a/ in comfortable pitch and loudness for at least 5 seconds for 15 trials. These voice samples were objectively analyzed to obtain the acoustic parameters of voice. The Intraclass Correlation Coefficients (ICCs) values of 3 to 15 trials for each acoustic parameters were measured to determine the number of trials of voice sample production that produce reliable measurement of acoustic parameters.

The finding of the present study demonstrated three voice sample production trials were required to obtain both acceptable and excellent reliability measurement for fundamental frequency, shimmer percent and harmonic-to-noise ratio. For jitter percent, at least four trials of voice sample production were required to obtain acceptable reliability and at least seven trials of voice sample production to acquire excellent reliability measurement. Based on the present study, it is recommended that a minimum of four trials of voice sample production are required to obtain at least acceptable reliability measurement for all acoustic parameters.

CHAPTER 1: INTRODUCTION

Acoustic voice analysis has been shown to be a useful and convenient tool in clinical voice assessment (Titze, 1995; Deliyski et al., 2005a). The most common acoustic parameters to describe the voice characteristics obtained from the acoustic analysis are fundamental frequency, jitter, shimmer, and harmonic-to-noise ratio (Stemple, Glaze, & Klaben, 2000; Teixeira & Fernandes, 2014). Current clinical practice in the acoustic analysis involves production of voice sample, usually in a sustained vowel, as steady as possible at comfortable pitch and loudness. This voice samples will then be analyzed to obtain the acoustic parameters.

Owing to the intra-subject variability, most of the time, the individual cannot produce the similar voice sample in each trials (Bough et al., 1996; Deliyski et al., 2005b). To ensure reliability measurement, the vowel sample is produced in few trials (Ziwei et al., 2014; Leong et al., 2013; Dejonckere et al, 2010; Stone & Rainey, 1991; Vogel, Fletcher, Snyder, Fredrickson, & Maruff, 2011; Bough, Heuer, Sataloff, Hills, & Cater, 1996). These voice samples are then analyzed to get the acoustic parameters. The final value of a particular acoustic parameter that will be used is derived from the average values of these trials (Franca, 2012; MacCallum, Zhang.Yu, & Jiang, 2011b; Vogel, Fletcher, Snyder, Fredrickson, & Maruff, 2011; Carding et al., 2004; Bough, Heuer, Sataloff, Hills, & Cater, 1996; Diercks et al., 2013).

Current clinical practice recommends an average of acoustic parameters from three trials (Titze, 1995) and this is also supported by the previous studies (e.g., Ziwei et al., 2014; Leong et al., 2013; Dejonckere et al, 2010; Stone & Rainey, 1991). However,

there are studies suggesting that five trials (Vogel, Fletcher, Snyder, Fredrickson, & Maruff, 2011), and up to fifteen trials (Bough, Heuer, Sataloff, Hills, & Cater, 1996) are required to obtain reliable measurement of the acoustic parameters. This uncertainty poses a question on how many voice sample production trials should be employed to ensure reliable measurement of each acoustic parameter. Due to this inconclusive finding and considering the lack of studies on this matter, further study to clarify this uncertainty is warranted.

1.1 Problem Statement

Due to the high intra-subject variability and to ensure reliability of measurement of acoustic parameters, voice sample production is done in few trials. Currently, there is inconclusive finding and limited studies on the number of trials required to be averaged in obtaining reliable measurement. This uncertainty needs to be addressed.

1.2 Study objectives

1.2.1 General

To investigate number of voice sample production trials required to obtain reliable measurement of acoustic parameters in acoustic analysis.

1.2.2 Specific

1. To measure each acoustic parameter in 15 voice sample production trials.
2. To determine the Intraclass Correlation Coefficients (ICCs) value of each acoustic parameter starting from 3 trials, and up to 15 trials.
3. To identify the number of trials that produce reliable measurement for each acoustic parameter.

1.3 Research questions

How many trials of voice sample are required to produce reliable measurement for each acoustic parameter?

CHAPTER 2: LITERATURE REVIEW

2.1 Acoustic voice analysis

Acoustic analysis provides objective and noninvasive measures of vocal function (Dejonckere et al., 2001; Rabinov et al., 1995; Schuckman, 2008). These include measurements of the human voice pitch (fundamental frequency) and loudness (amplitude), frequency and amplitude perturbation indices (jitter and shimmer), estimates of the proportion of aperiodicity (signal-to-noise ratio) (MacCallum et al., 2011b; Brockmann-Bauser, 2012).

2.2 Acoustic parameters

Acoustic parameters correlate with the physiology of voice production and acoustic signals obtained through acoustic analysis (Brockmann et al., 2011; Dejonckere et al., 2001). There are a few parameters which are widely used in the measurement and also the voice analysis such as fundamental frequency, jitter, shimmer and harmonic-to-noise ratio (Franca, 2012; Smits, Ceuppens, & Bodt, 2005).

Fundamental frequency is the lowest frequency in a periodic waveform (Smits, et al., 2005). Fundamental frequency is an important parameter in both the functional and anatomical larynx assessment, and it is determined by the number of cycles produced by the vocal folds per second (Felippe et al., 2006). It refers to the rate of the vocal fold vibration and also reflects habitual pitch (Dehqan et al., 2010). Fundamental frequency has proven to be the most uniform among all of the acoustic parameters when

considering different acoustic analysis systems, and the one less sensitive to voice recording characteristics (Morris & Brown, 1996).

Jitter or frequency perturbation of voice represents the variability or perturbation of the fundamental frequency from one cycle to the next cycle (Baken & Orlikoff, 2000; Wertzner et al., 2005). There are many types of jitter such as jitter absolute, relative jitter, relative average perturbation (rap) and the period perturbation quotient (ppq5). It is thus a fundamental frequency related measurement (Dejonckere et al., 2001).

For shimmer, it is a measure of amplitude instability (Carroll et al., 2006) and it is related to the amplitude or the intensity of sound waves and vocal emission (Wertzner et al., 2005). It is a short-term, cycle-to-cycle variability in vocal fold vibration amplitude (Franca, 2012; Titze, 1995). There are a few types of shimmer such as shimmer (dB), shimmer relative, three-point amplitude perturbation quotient (apq3) and five-point amplitude perturbation quotient (apq5).

The harmonic-to-noise ratio is a general evaluation of the noise presence in the analyzed signal (Smits, et al., 2005; Wertzner, et al., 2005) and reflects the relative contribution of periodic (i.e., harmonic) and aperiodic (i.e., noise) components of the acoustic signal (Stemple, Glaze, & Klaben, 2000; Ferrand, 2002). Normal voice should have a low noise-to-harmonic ratio (Smits, et al., 2005).

The normative data of the acoustic parameters in males are shown in Table 2.1 whereas the normative data of the acoustic parameters in females are shown in Table 2.2.

Table 2.1 The normative data of acoustic parameters in males

Reference	Stimulus (Instrument)	Fundamental frequency (Hz)	Jitter percent (%)	Shimmer percent (%)	Harmonic-to- noise ratio
Chuah	/i/ (MDVP)	132.47	0.88	1.64	18.59
Ting et al.	/a/ (PRAAT)	131.40	0.38	1.87	-
Dehqan et al.	/a/ (Dr.Speech)	113.10	0.24	1.22	18.49

Table 2.2 The normative data of acoustic parameters in females

Reference	Stimulus (Instrument)	Fundamental frequency (Hz)	Jitter percent (%)	Shimmer percent (%)	Harmonic-to- noise ratio
Chuah	/i/ (MDVP)	243.55	0.81	1.64	19.79
Ting et al.	/a/ (PRAAT)	233.28	0.33	1.87	-
Dehqan et al.	/a/ (Dr.Speech)	214.53	0.23	1.23	18.50

2.3 Reliability of acoustic parameters measurement

A few studies examined the reliability measurement of the acoustic parameters (Burris et al., 2014; Leong et al., 2013; Dwire & McCauley, 1995; Deliyski et al., 2005a; Smits, et al., 2005). Most commonly, reliability of acoustic voice analysis is evaluated due to the intra-subject variability affects measurements taken over the trials (Bough et al., 1996; Deliyski et al., 2005a). On account of the intra-subject variability, which is incapability of the individual to produce the same voice sample for each trial, it affects in obtaining the reliable measurement (Bough et al., 1996). To ensure reliable measurement, multiple trials of sustained vowels were recorded in order to obtain reliable measures (Deliyski et al., 2005a; Bough et al., 1996; Leong et al., 2013; Hill et al., 2013). Therefore, it is possible that recording multiple voice samples and averaging the results, as suggested by Titze (1995) may improve the reliability. This averaging method has been employed in current clinical practice of voice analysis.

2.4 Number of voice sample production trials to get reliable acoustic parameters measurement

Different studies have dissimilar opinions in terms of number of voice sample production trials in acoustic analysis, such as three trials (Ziwei et al., 2014; Leong et al., 2013; Dejonckere et al, 2010; Stone & Rainey, 1991), five trials (Vogel, Fletcher, Snyder, Fredrickson, & Maruff, 2011), and up to fifteen trials (Bough, Heuer, Sataloff, Hills, & Cater, 1996). The findings from the previous studies on the number of trials required for obtaining reliable acoustic parameters measurement is shown in Table 2.3.

Table 2.3 Number of trials required for obtaining reliable acoustic parameters measurement

Study	Participants		Number of trials			
	N	Mean age	Fundamental	Jitter	Shimmer	Harmonic-to-
	Gender	(years)	frequency	percent	percent	noise ratio
Stone & Rainey (2013)	24 Female	26	3	3	3	3
Bough et al. (1996)	14 6 Males, 8 Females	26 Men (36) Women (31)	3	>6	>6	3

2.5 Intraclass correlation coefficients

The reliability measurement of the acoustic parameters is based on the Intraclass Correlation Coefficient (ICCs). ICCs are one of alternative statistics for measuring homogeneity of the pairs of measurements and larger sets of measurements (McGraw & Wong, 1996). ICCs values can range from 0 to 1. Based on Fleiss (1986) as cited in Hill et al. (2013), the ICCs rating are classified into different categories: excellent reliability (>0.75), fair to good reliability ($0.40 - 0.75$) and poor reliability (<0.40). Based on Awan et al. (2013), Bruton et al. (2000), and Chinn (1991) studied on reliability, it has been recommended that ICC values more than 0.60 can be accepted to be useful in obtaining acceptable reliability.

CHAPTER 3: METHODOLOGY

3.1 Study design

The present study was conducted in the Klinik Pertuturan Bahasa (KPB), Pusat Pengajian Sains Kesihatan (PPSK), Universiti Sains Malaysia Kampus Kesihatan (USMKK), Kelantan. This cross-sectional study recruited undergraduate students of USMKK as the participants. An ethical approval was obtained from the Human Ethics Committee of Universiti Sains Malaysia (USM) (Appendix A), prior to the data collection. The study design of the present study is as shown in the Figure 1.

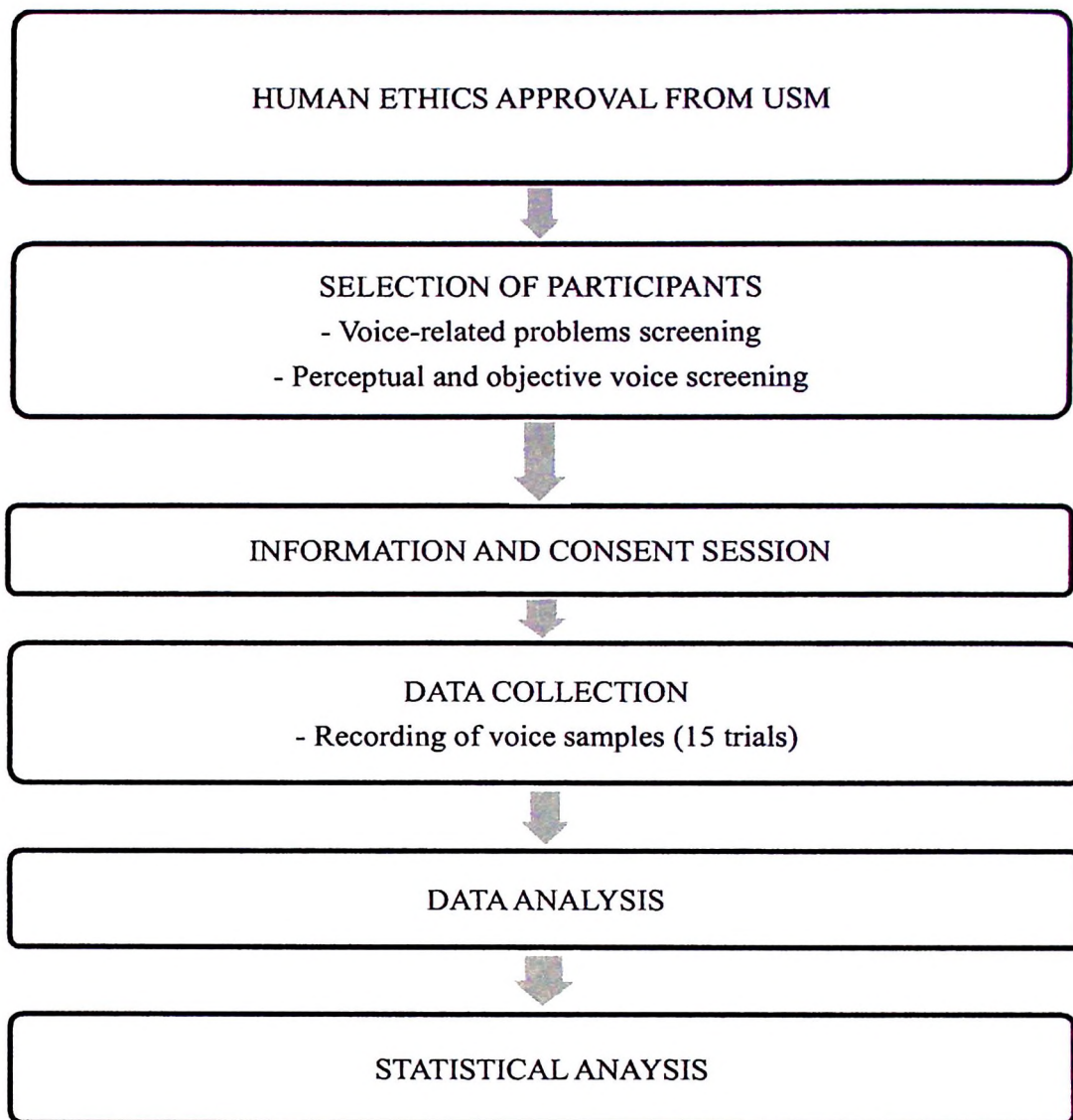


Figure 1: The study design

3.2 Instruments

The voice samples for the voice screening and data collection during the selection of participants were recorded using the PRAAT software. Unidirectional dynamic hand-held microphone (SHURE SM 48) connected to a 13-inch MacBook Pro laptop containing the PRAAT software was used for the recording of the voice samples in both of the voice screening task and data collection. The computer specifications are as follow: Intel HD Graphics 3000 384 MB; 2.3 GHz Intel Core i5; 4 GB 1333 MHz DDR3; OS X Yosemite, Version 10.10.1; Serial Number: C17FL0BVDH2G. The sampling rate for all audio recording was set at 44,100 Hz.

3.3 Voice sample

The most commonly used voice sample for acoustic voice analysis is a sustained vowel because it represents relatively time-invariant phonation and is not affected by participant's articulation such as speech rate, vocal pauses, phonetic context, and stress (Maryn et al., 2010; Law et al., 2012). Additionally, a sustained vowel contains no linguistic loading, resulting in relative immunity from influences related to dialect and region, language, and cognition (Franca, 2012; Maryn et al., 2010). Few sustained vowels have been used in the previous studies involving acoustic analysis, e.g., /a/ (Araújo et al., 2003; Amir, et al., 2009; MacCallum et al., 2011a), /e/ (Batalla et al., 2014; Kilic et al., 2004) and /i/ (Ooi, 2013; Hee, 2014; Gelfer, 1995 as cited in Brockmann et al., 2011). The present study used /a/ because it is the most commonly used vowel for clinical and research purposes (Araújo et al., 2003).

3.4 Voice recording procedures

The voice recording process for both voice screening and data collection were conducted according to the protocols recommended by the Committee on Phoniatrics of the European Laryngological Society (Dejonckere et al., 2001) for all the trials. The recordings were done in a sound treated room with an ambient noise less than 50 dB measured by sound level meter (SLM) before the recording started. The microphone was positioned at a distance of 4 cm and an angle of 45° from the participant's mouth (Titze, 1995), in order to reduce aerodynamic noise in the voice samples.

3.5 Participants

Convenience sampling was used to recruit the participants in the present study. Sample size was calculated by using sample size calculator (Unit of Biostatistics and Research Methodology, 2015). This sample size calculation was developed based on a reference from sample size optimal designs for reliability studies that proposed by Walter, Eliasziw & Donner (1998). By choosing observation/subject of 3, significance level of 0.05, power of 0.80, acceptable reliability of 0.80, and the expected reliability of 0.90, the minimum sample size is 33. Based on the study by Brockmann et al. (2011), there were differences in terms of the acoustic parameters between male and female voices. It is desirable for both gender to be included in the present study but due to limited timeframe, only male individuals were recruited in the present study.

Only individuals without any indication of voice related problems that affected the voice mechanism were included in the present study. This voice-related problems

were assessed using the medical and voice history questionnaires (Lundy et al., 1999) (Appendix B). This questionnaire aimed to obtain relevant voice-related information and abnormalities. In this session of self-completed questionnaire, the investigator was present to clarify any confusion. Individuals with voice-related problems were identified if they answered “Yes” for some of the questions in the questionnaires and were not be recruited in the present study. It was observed that most participants took caffeinated drinks at least once a week. Due to the limited study population, these individuals were also included in the present study as caffeinated drinks did not significantly affect voice production according to the study by Erickson-Levendoski and Sivasankar (2011).

Individuals who passed the screening using the medical and voice history questionnaires underwent perceptual and objective voice screening to further exclude individuals with issues in their voice qualities. This perceptual voice screening was administered by a speech-language pathologist (SLP) specialized in voice based on the voice screening form (Appendix C). This form was specifically developed based on the Consensus Auditory-Perceptual Evaluation-Voice (CAPE-V) (ASHA, 2006). In the perceptual voice screening, each individual was asked to perform a few voicing tasks, comprising of sustaining vowel /a/, production of short phrases and passage reading (Grandfather passage) (Appendix D). The voice samples were recorded using the PRAAT software and these data were saved in the thumb drive for the SLP to rate.

For objective voice screening, the same voice sample used in the perceptual voice screening task was used to further exclude the participants. Individuals who exhibited abnormal values of jitter percent were excluded from the data analysis based

on the database of jitter percent by Ting et al. (2011). Jitter, or jitter percent in the present study was used to exclude the participant because of its relative better sensitivity in detecting voice change (Brockmann et al., 2011).

3.6 Data collection

Due to practicality and feasibility issues in the perceptual and objective voice screening procedures, exclusion of individuals with issues in their voice qualities were not done at this point. The exclusion processes based on these two screenings were done after the data collection and before the data analysis. Any individual who passed the medical and voice history questionnaires were invited to take part in the present study. They were provided with the project information sheet (Appendix E) and given an informed consent form (Appendix G) before the commencement of the data collection. In this session, the individuals were informed that this study was voluntarily basis and they could refuse or stop their participation in this study at any time.

3.6.1 Procedures

Each participant was required to be seated in a comfortable posture with the hands on the knees and the head in neutral and comfortable posture for each recording of voice samples. Prior to the recording, the investigator prepared the participants by explaining to the participant to produce sustained /a/ at comfortable pitch and loudness. After that, the investigator demonstrated the task by verbally sustaining the vowel /a/, followed by one trial of practice before the recording commenced.

The recording session was set up according to the recording protocols as mentioned above. Then, the participants were then requested to produce vowel /a/ verbally for 5 seconds after the investigator gave a gestural sign. This voice sample was directly recorded to the laptop with PRAAT software as described in the instrument section. The same procedures, but without the participants' preparation were repeated for the subsequent 2 to 15 trials. There was a break of 60 seconds in between the trials.

3.7 Data analysis

Only the recorded voice samples of individuals that passed the perceptual and objective voice screenings were included for the data analysis. For each 5 seconds of voice sample, a middle segment of 1 second with waveform that considered to be the most stable based on visual judgment was selected to exclude variability during the voice onset and offset (Brockmann et al., 2011). The edited voice samples were analyzed by using the PRAAT to get the acoustic parameters i.e., fundamental frequency, jitter percent, shimmer percent, and harmonic-to-noise ratio. For each acoustic parameter, there were 15 values from 15 voice sample production trials.

3.8 Statistical analysis

The data for the values of the ICCs for the acoustic parameters of voice in the present study were measured by using a two-way mixed model, absolute agreement, average-measures ICC (McGraw & Wong, 1996). The ICCs rating of excellent reliability (>0.75), fair to good reliability ($0.40 - 0.75$) and poor reliability (<0.40) based on Fleiss (1986), as cited in Hill et al. (2013) was used as the reference in the

present study. The ICCs values more than 0.75 can achieve excellent reliability, but Awan et al. (2013) stated that ICC values at least 0.60 can be accepted to be useful in obtaining acceptable reliability.

CHAPTER 4: RESULTS

4.1 Introduction

The first part of the result section involved summarization of participants' demography. Descriptive statistics such as frequency, mean, standard deviation and range were used to describe participants' demography. The second part is about descriptive analysis of each acoustic parameter based on voice samples production trials. The third part involved summarization of the ICCs values for each acoustic parameter from 3 trials to 15 trials of voice sample production. All statistical tests were computed using Statistical Program for Social Science (SPSS version 22 for Windows).

4.2 Participant demographics

A total of 53 participants from USMKK were recruited in the present study. However, only 33 participants were included in the data analysis after the perceptual and objective voice screening. The participants' demography is depicted in Table 4.1.

Table 4.1 Participant demographics

Race	N	Age (years)		
		Mean	SD	Range
Malay	25	22.12	1.269	20 - 25
Chinese	8	22.75	0.886	21 - 24

4.3 Summary of the mean, standard deviation and range values for the acoustic parameters according to voice production trials

The data of the acoustic parameters in the present study were tabulated in the following sections.

4.3.1 Fundamental frequency

Table 4.2 represents the descriptive analysis of fundamental frequency, starting from 3 trials to 15 trials of voice sample production. The result indicated that the mean values of fundamental frequency showed minimal variation over the trials.

Table 4.2 Mean, standard deviation and range values for fundamental frequency

Number of trials	Mean	SD	Range
3	125.955	15.676	103.230 – 162.245
4	126.260	15.282	103.148 – 162.715
5	126.598	15.319	103.153 – 163.893
6	126.860	15.280	103.152 – 163.798
7	127.001	15.261	103.540 – 164.633
8	127.283	15.279	103.941 – 165.837
9	127.533	15.427	104.825 – 167.021
10	127.680	15.457	104.390 – 168.051
11	127.872	15.582	103.903 – 168.715
12	127.961	15.637	103.561 – 169.374
13	128.034	15.657	103.525 – 169.935
14	128.124	15.781	103.723 – 170.580
15	128.257	15.880	103.493 – 171.324

4.3.2 Jitter percent

Table 4.3 represents the descriptive analysis of jitter percent, starting from 3 trials to 15 trials of voice sample production. The result indicated that the mean values of jitter percent showed minimal variation over the trials.

Table 4.3 Mean, standard deviation and range values for jitter percent

Number of trials	Mean	SD	Range
3	0.325	0.104	0.159 – 0.566
4	0.327	0.114	0.158 – 0.604
5	0.323	0.110	0.156 – 0.658
6	0.315	0.102	0.147 – 0.606
7	0.314	0.102	0.147 – 0.629
8	0.308	0.095	0.156 – 0.589
9	0.307	0.096	0.157 – 0.597
10	0.307	0.099	0.161 – 0.624
11	0.305	0.097	0.162 – 0.607
12	0.305	0.098	0.160 – 0.592
13	0.309	0.109	0.160 – 0.681
14	0.313	0.117	0.159 – 0.747
15	0.314	0.117	0.160 – 0.746

4.3.3 Shimmer percent

Table 4.4 represents the descriptive analysis of shimmer percent, starting from 3 trials to 15 trials of voice sample production. The result indicated that the mean values of the shimmer percent showed minimal variation over the trials.

Table 4.4 Mean, standard deviation and range values for shimmer percent

Number of trials	Mean	SD	Range
3	10.304	3.729	3.593 – 17.004
4	10.121	3.595	3.514 – 16.617
5	10.082	3.558	3.594 – 16.920
6	9.894	3.394	3.542 – 16.191
7	9.801	3.222	3.596 – 16.391
8	9.726	3.138	3.630 – 16.654
9	9.716	3.174	3.635 – 16.809
10	9.700	3.256	3.660 – 17.016
11	9.661	3.225	3.790 – 17.033
12	9.624	3.263	3.832 – 17.060
13	9.626	3.268	3.924 – 17.412
14	9.608	3.279	3.986 – 17.618
15	9.613	3.262	4.074 – 17.677

4.3.4 Harmonic-to-noise ratio

Table 4.5 represents the descriptive analysis of harmonic-to-noise ratio of voice, starting from 3 trials to 15 trials of voice sample production. The result indicated that the mean values of the harmonic-to-noise ratio showed minimal variation over the trials.

Table 4.5 Mean, standard deviation and range values for harmonic-to-noise ratio

Number of trials	Mean	SD	Range
3	13.087	3.660	6.670 – 21.260
4	13.262	3.611	7.760 – 22.122
5	13.290	3.445	7.703 – 22.034
6	13.446	3.360	8.017 – 22.170
7	13.513	3.196	8.028 – 21.861
8	13.593	3.094	8.172 – 21.565
9	13.637	3.141	7.927 – 21.870
10	13.631	3.179	7.737 – 21.716
11	13.691	3.164	7.841 – 21.401
12	13.736	3.177	7.941 – 21.450
13	13.744	3.167	7.666 – 21.424
14	13.762	3.173	7.396 – 21.254
15	13.749	3.198	7.280 – 21.113

4.4 The ICCs values of each acoustic parameter over the trials

The data for the values of the ICCs for the acoustic parameters in the present study were analyzed and shown in the following section. The ICCs rating based on Fleiss (1986), as cited in Hill et al. (2013) was used as the reference in the present study.

4.4.1 Fundamental frequency

Table 4.6 represents the ICC values of voice sample production trials for fundamental frequency.

Table 4.6 The ICC values of voice sample production trials for fundamental frequency

Number of trials	ICCs	95% Confidence Interval	
		Lower Bound	Upper Bound
3	0.988	0.977	0.994
4	0.987	0.978	0.993
5	0.990	0.983	0.995
6	0.990	0.984	0.995
7	0.991	0.986	0.995
8	0.992	0.986	0.995
9	0.992	0.988	0.996
10	0.993	0.988	0.996
11	0.993	0.989	0.996
12	0.994	0.990	0.996
13	0.994	0.991	0.997
14	0.995	0.992	0.997
15	0.995	0.992	0.997

Overall, there is a slight variation of ICCs values across trials. The ICCs value slightly decreases with 4 trials of voice sample production and then gradually increases

up to 15 trials. However, the ICCs values starting from 3 trials to 15 trials were still in the excellent range.

4.4.2 Jitter percent

Table 4.7 represents the ICC values of voice sample production trials for jitter percent.

Table 4.7 The ICC values of voice sample production trials for jitter percent

Number of trials	ICCs	95% Confidence Interval	
		Lower Bound	Upper Bound
3	0.575	0.250	0.775
4	0.623	0.357	0.796
5	0.706	0.511	0.839
6	0.737	0.570	0.854
7	0.790	0.660	0.883
8	0.801	0.680	0.889
9	0.840	0.744	0.910
10	0.871	0.794	0.927
11	0.885	0.817	0.935
12	0.893	0.831	0.940
13	0.895	0.834	0.941
14	0.905	0.850	0.946
15	0.912	0.861	0.950

In general, a more variable ICC values was seen across trials for the jitter percent. There was a steady increment in the ICC values starting from 3 trials to 15 trials. The trials below 6 showed fair to good reliability but after 7 trials, excellent reliability is achieved.

4.4.3 Shimmer percent

Table 4.8 represents the ICC values of voice sample production trials for shimmer percent.

Table 4.8 The ICC values of voice sample production trials for shimmer percent

Number of trials	ICCs	95% Confidence Interval	
		Lower Bound	Upper Bound
3	0.818	0.674	0.904
4	0.855	0.754	0.922
5	0.887	0.812	0.938
6	0.894	0.827	0.941
7	0.886	0.815	0.937
8	0.900	0.839	0.944
9	0.913	0.861	0.951
10	0.927	0.884	0.959
11	0.934	0.896	0.963
12	0.943	0.909	0.968
13	0.945	0.912	0.969
14	0.950	0.921	0.972
15	0.953	0.926	0.974

In general, a slight variation of ICC values was seen across trials for the shimmer percent. There was a progressive increase of ICC values from 3 trials to 6 trials of voice sample production. At the 7 trials, the ICC values decreases but it continues to increase for the subsequent trials of voice sample production. Although there was a variation, all of the trials were represented in the range of excellent reliability.

4.4.4 Harmonic-to-noise ratio

Table 4.9 represents the ICC values of voice sample production trials for harmonic-to-noise ratio.

Table 4.9 The ICC values of voice sample production trials for harmonic-to-noise ratio

Number of trials	ICCs	95% Confidence Interval	
		Lower Bound	Upper Bound
3	0.905	0.832	0.950
4	0.923	0.869	0.958
5	0.922	0.871	0.957
6	0.919	0.868	0.955
7	0.919	0.869	0.955
8	0.923	0.876	0.957
9	0.931	0.889	0.961
10	0.940	0.904	0.966
11	0.943	0.910	0.968
12	0.948	0.917	0.971
13	0.951	0.922	0.972
14	0.955	0.928	0.974
15	0.958	0.934	0.976

In general, a slight variation of ICC values was seen across trials for the harmonic-to-noise ratio. There was a progressive increase of ICC values from 3 trials to 4 trials of voice sample production. At the 5 trials, the ICC values decreases but it continues to increase for the subsequent trials of voice sample production. Although there was a variation, all of the trials were represented in the range of excellent reliability.