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ABSTRACT

OBJECTIVE MEASURES OF VOCAL PRODUCTION
DURING THE COURSE OF SINGING STUDY

By

Sharon Lynn Radionoff

The purpose of this study was to determine if normal voice functions for trained singers differ from published normative data for objective voice analysis. Acoustic, phonatory, and respiratory measures were collected from 28 subjects enrolled in applied voice lessons at Rice University, Shepherd School of Music, and diagnosed as having a normal larynx or symptoms of reflux.

On each of three occasions, acoustic data was collected using a SONY DAT recorder for subsequent analysis with the Computer Speech Lab (CSL) Multi-Dimensional Voice Program (MDVP). Phonatory measures (16) secured on-line and respiratory measures (4) obtained on-line using the Tamarac Presto 'Flash' spirometer were logged. A total of 18 measures were analyzed for each vowel, /ɑ/, /i/, /u/, using both spoken and sung phonation on each of three occasions.

Interrelated acoustic, phonatory, and respiratory measures were investigated using repeated-measures analysis of variance to determine if any patterns of change were present over the eight-month training program. When non-equivalent means over the three occasions were detected, simultaneous *post hoc* trend procedures were employed to determine the particular nature of the trend following the Dunn-Bonferroni strategy. The results indicated that the current norms for 67 measures were in need of modification. In the acoustic domain alone (across the vowels and phonating conditions) 56.5% of the

measures were not corroborated. Measures requiring modification in the phonatory and respiratory domains were 12.5% and 25% respectively.
A perceptible disparity in norms apparently exists for spoken and sung phonating conditions. To clarify and corroborate this distinction it is necessary to collect and analyze data from numerous larger samples. Such cross validation studies will yield stable norms for use in evaluating singers. The magnitude and patterns of the disparity in norms for measures in the acoustic domain has particular implications for clinical assessment and prescription, but more importantly for evolving pedagogical designs.

The results are presented in the Appendices (Volume II). Customary indicators are used in all three domains. Tabular form as well as graphic representation are contained in Volume II.

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This dissertation is dedicated to my parents, Leonard and Linda Radionoff, with overflowing, deep, heartfelt gratitude for their never ending love, support, and constant encouragement.

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CHAPTER I

INTRODUCTION

Background for the Study

The art, craft, and teaching of singing and the practice of medicine have existed as separate entities for centuries. Early practitioners acknowledged the interrelationships between singing and medicine, but possessed only rudimentary equipment and limited knowledge of the anatomy and physiology of the phonation process.

The old master teachers taught by subjectively listening and watching. Many pedagogues have had some excellent results by using subjective imagery with their students. While some singers may learn well by imagery, others may need intellectual concepts. Most vocal studios are filled with students encompassing a wide range of vocal abilities and cognitive processes. Some students have a more heightened visual than auditory acuity and many, if not all, may well benefit from some objective feedback. It is one thing for the teacher to state that the singer is using harsh glottal attacks and quite another for the singer to be able to watch and modify the vocal onset by observing digital representation of his/her voice on a screen or real time digital display.

Until recently it has not been possible to quantify the characteristics of sung sound in explicit detail. However, the development of technology within the field of voice science over the past five to seven years has provided powerful equipment and greatly expanded the knowledge base. Further, the rapid pace of this development requires constant attention for one to stay abreast of the expanding capabilities. Today, technology as applied to the singing voice has provided for significant pedagogical advantages. One example of how this technology is being put to use for pedagogical purposes can be found at Professor

Richard Miller's *Otto B. Schoepfle Vocal Arts Laboratory* at the Oberlin Conservatory of Music in Oberlin, Ohio. There, it is possible for the student to be able to not only hear, but to see and recognize through precise communicable language what the teacher also hears and sees. Obvious implications for the vocal studio are recognized by Miller and other authorities in the field.

Not only are there expanding implications of the technology in the field of pedagogy, but also for clinical care wherein quantifiable measures are critical. This information is used to signal what to look for in stroboscopy. While stroboscopy is useful for the laryngologist to make medical diagnoses and for the speech-language pathologist to diagnose the functional aspects of phonation, quantified, objective measures are still lacking for the phonation observed. The development of apparatus such as the Computer Speech Lab (CSL) by Kay Elemetrics, enables one to quantify acoustic measures where phonation is produced naturally, i.e., with body posture in a neutral position. Also pre-,post-, and follow-up objective measures in surgical cases allow for objective quantification of vocal outcome and improvement.

In regard to clinical care, a basic core of normative data is currently in use to aid in the differentiation of normal and pathological voices. Most of these data were obtained on non-trained singers and typically involved the analysis of speech production. The research question for this investigation then becomes "Is this normative data appropriate or valid for use in objectively assessing trained singers?"

Need for the Study

Why is it necessary to collect quantifiable data of sung production? Historically, many extraordinary singers have had brilliant careers without the aid of a lot of numbers--Manuel Garcia Sr., Jenny Lind, Jan Pierce, Richard Tucker,

Judith Blegen, Beverly Sills, Fredrica Von Stade, and Robert Merrill but to name a few. Furthermore, what is the need for more numbers when there already exist published spoken normative data such as that reported in Baken's Clinical Measurement of Speech and Voice, and Hirano's Clinical Examination of Voice: Disorders of Human Communication? Once again, most of the objective measurements of voice have been collected from non-trained singers and typically involved the analysis of speech production. So again the question of relevance is at issue. Are the measurements of jitter (pitch) and shimmer (intensity) variation the same for both spoken and sung production? Also do singers produce comparable results of jitter and shimmer during spoken phonation to that of non-trained singers?

The existence of a pool of normative data for sung phonation may well have both pedagogical and clinical implication, especially if it differs from spoken phonation. Again, within the vocal studio, different students will use different processing/learning modes. Some would indeed benefit from visual feedback of their own production versus normal production. Also, if a student begins having vocal problems such as hoarseness, loss of upper register, or loss of control of dynamics, it is critical to specify what the problem is so that the proper treatment can be implemented. If the singer continues to exhibit a deviation from the norm, the vocal pedagogue should encourage evaluation by a professional voice care team. Clinically this pool of normative data for sung phonation may well facilitate determining when and how singers deviate from the norm and afford identification of problem characteristics so that appropriate treatment may be applied to restore the voice to a healthy state.

In order for the results of this study to be generalized to a larger population, it is necessary to obtain normative data from evaluation of singers at different intervals of training and students from more than one studio. This is

necessary since singers who experience vocal difficulties will not all be at the same stage of development or come from only one vocal studio.

The main purpose of this study was to determine expected function of normal singers among normal training levels for various objective measures. An additional task of this study was to measure and analyze for the singing voice the most common forms of perturbation that have been stated in the literature. Previous studies investigating jitter and shimmer of spoken phonation have used so many different measures that it has been difficult to compare and generalize results from study to study.

Hypothesis

During the course of this study the following hypothesis was examined: Normal voice functions for trained singers differ from published normative data for objective voice analysis.

Limitations of the Study

This study tests only trained singers and does not provide its own control group of speakers. However, the control group in essence, exists in the normative data for speakers that have been accepted by the scientific community. These data for speakers have been studied widely, and the normative results have been reported in numerous laboratories. The concern of this research is directed specifically toward the question of whether these widely accepted norms are valid for routine voice analysis of professional singers.

Procedures for Study

Only healthy volunteers were solicited for inclusion in the study. Those who chose to be involved in this study were 28 voice majors , divided among

three vocal studios, from Rice University, Shepherd School of Music. Health was confirmed through a questionnaire and an examination by a laryngologist specialized in voice disorders. Volunteers with any noteworthy health or laryngeal abnormality were excluded. Each subject performed a standard protocol of phonatory tasks which were analyzed by means of commercially available equipment used widely in voice laboratories. There were three points in time at which data collections of objective measures were secured. At each of these points the vocal production of the subjects, all at various levels of training, were obtained. The data were recorded with the same apparatus and procedures and were subjected to appropriate statistical analysis.

Definitions

Amplitude Tremor--A regular (periodic) long term amplitude variation (an element of vibrato).

Formant--A harmonic that has become strengthened as the fundamental frequency and corresponding harmonics pass through the resonator (supraglottic vocal tract).

Frequency Tremor--A periodic (regular) pitch modulation of the voice (an element of vibrato).

Glottis--The airspace between the vocal folds.

Harmonic spectral energy--The energy encompassing the highest peak of the harmonic and two points on either side of the highest peak (every harmonic is represented by 5 points) in each spectrum. The distance from harmonic to harmonic is about 20 points.

Inharmonic spectral energy--The energy encompassing the 15 points between harmonics that is not included in the analysis of harmonic spectral energy in each spectrum.

Pathological voices--The voices that exhibit some type of voice abnormality which can be due to a nodule, polyp, cyst or other type of pathology.

Period-to-period variability--Synonymous with cycle-to-cycle variability.

Phonation--The process of creating sound by the vocal folds.

Pitch Extraction Errors--The process of pitch extraction may exhibit errors in the peak picking method. This can occur because of strong subharmonics or instrumental errors (when the autocorrelation function cannot detect periodicity of the glottal pulses).

Rigid telescope--A rigid tube which includes a light source and a series of prisms to reflect an image on a lens or camera.

Smoothing Factor--The process of taking sets of averages of cycles.

Stroboscopy--The process of viewing the vocal folds by using either a rigid telescope or flexible fiberoptic scope which is attached to a flashing light source whose rate of flashing may be synchronized or desynchronized with the frequency of vocal fold motion or movement.

Supraglottic Vocal Tract--It is comprised of the supraglottic larynx, tongue, lips, palate, pharynx, and nasal cavity (also known as the resonator).

Vocal Folds--They are the vibrators of phonation. They are composite structures consisting of five layers: A thin, lubricated epithelium covering, three layers of lamina propria, and the thyroatytenoid or vocalis muscle which makes up the body of the vocal fold (it is also one of the intrinsic laryngeal muscles) (commonly known as the vocal cords).

Objective Measures - include acoustic, phonatory, and respiratory measures.

A. Acoustic Measures

1. Fundamental Frequency (F_O)--It corresponds to the "pitch" of the voice measured in cycles per second or Hertz (Hz).
2. Conversational sample average fundamental frequency--It is a sample of the subject's conversational average speaking fundamental frequency.

Fundamental Frequency Perturbation Measurements

3. Jita (Absolute Jitter) --It is a discreet measure of very short term (cycle to cycle) variation of the pitch periods expressed in microseconds. This parameter is dependent on the fundamental frequency of the voicing sample. Therefore, normative data differs significantly for men and women. Higher pitch results in lower Jita. Pitch extraction errors may affect absolute jitter significantly (Iwata & Von Leden (1970).
4. JITT (Jitter Percent)--It is a relative measure of very short term (cycle-to-cycle) variation of the pitch periods expressed in percent. The influence of the average fundamental frequency is significantly reduced. This parameter is very sensitive to pitch variations. However, pitch extraction errors may significantly affect Jitter Percent.
5. RAP (Relative Average Perturbation)--It is a relative evaluation of short term (cycle-to-cycle) variation of the pitch periods expressed in percent. However this measurement uses a smoothing factor of 3 periods which reduces the pitch

variation sensitivity, but it is also less sensitive to pitch extraction errors (Koike, 1973).

6. PPQ (Pitch Period Perturbation Quotient)--It is a relative evaluation of short term (cycle-to-cycle) variation of the pitch periods expressed in percent. However, this measure uses a smoothing factor of 5 periods which reduces the pitch extraction error sensitivity. It is also less sensitive to period-to-period variations, but aptly describes short-term pitch perturbation. (Koike & Calcatera, 1977).
7. sPPQ (Smoothed Pitch Perturbation Quotient)--It is a relative evaluation of long-term variation of the pitch period within the analyzed voice sample expressed in percent. This measure uses a smoothing factor of 55 periods. sPPQ is most sensitive to regular long-term variations within a period near and above 55 pitch periods.
8. vFo (Coefficient of Fundamental Frequency Variation)--This measure, expressed in percent, computes the relative standard deviation of the fundamental frequency. It is the ratio of the standard deviation of the period-to-period variation to the average fundamental frequency. It increases regardless of the type of pitch variation, whether, jitter, rising or falling pitch, or frequency tremors .

Amplitude Perturbation Measurements

9. Shimmer in dB--It is a measure of very short term (cycle-to-cycle) variation of the peak-to-peak amplitude expressed in decibels. It is very sensitive to the amplitude variations

occurring between consecutive pitch periods. Pitch extraction errors may affect shimmer significantly (Iwata & von Leden, 1970, Horii, 1980).

10. SHIM (Shimmer Percent)--It is the same as Shimmer dB but expressed in percent. Both are relative evaluations of the same type of amplitude perturbation but they use different measures for this result: either percent or dB. (Iwata & von Leden, 1970).
11. APQ (Amplitude Perturbation Quotient)--It is a relative evaluation of short term (cycle-to-cycle) variation of peak-to-peak amplitude expressed in percent. This measure uses a smoothing factor of 11 periods. It is less sensitive to period-to-period amplitude variations, but less affected by pitch extraction errors (Takahashi and Koike, 1975, Koike, Takahashi, and Calcaterra (1977).
12. sAPQ (Smoothed Amplitude Perturbation Quotient)--It is a relative evaluation of long-term variation of the peak-to-peak amplitude within the analyzed voice sample expressed in percent. This measure uses a smoothing factor of 55 periods. sAPQ is most sensitive to regular long-term variations within a period near and above 55 pitch periods.
13. vAm (Coefficient of Amplitude Variation)--This measure, expressed in percent, computes the relative standard deviation of the peak-to-peak amplitude. It increases regardless of the type of amplitude variation, whether, shimmer, or amplitude tremors.

Noise Related Measurements

14. NHR (Noise to Harmonic Ratio)--It is a general evaluation of noise present in the signal and includes jitter, shimmer, and turbulent noise. It is the ratio of inharmonic energy from 1500 to 4500 Hz to harmonic spectral energy in the range of 70-4500 Hz.
15. VTI (Voice Turbulence Index)--It is a measure of the relative energy level of high frequency noise. It is the ratio of spectral inharmonic energy at 2800-5800 Hz to spectral harmonic energy at 70-4500 Hz.
16. SPI (Soft Phonation Index)--It is a measure of the ratio of lower frequency harmonic energy at 70-1600 Hz to higher frequency harmonic energy at 1600-4000 Hz. If the SPI is low, then the spectral analysis will show well defined higher formants.

Tremor Measurements

17. FTRI (Fo-Tremor Intensity Index)--It is the average ratio of the frequency magnitude of the most intensive low-frequency modulating component (F_O tremor) to the total frequency magnitude of the analyzed sample. The algorithm for tremor analysis determines the strongest periodic frequency modulation of the voice. This measure is expressed in percent.
18. ATRI (Amplitude Tremor Intensity Index)--It is the average ratio of the amplitude of the most intensive low-frequency amplitude modulating component (amplitude tremor)to the

total amplitude of the analyzed sample. The algorithm for tremor analysis determines the strongest periodic amplitude modulation of the voice. This measure is expressed in percent.

19. Fftr (Fo-Tremor Frequency)--It is expressed in Hz. It shows the frequency of the most intensive low -frequency Fo-modulating component in the specified Fo-tremor analysis range. It is dependent on FTRI reaching the specified threshold in order to be computed.
20. Fatr (Amplitude Tremor Frequency)--It is expressed in Hz. It shows the frequency of the most intensive low-frequency amplitude-modulating component in the specified amplitude-tremor analysis range. It is dependent on ATRI reaching the specified threshold in order to be computed.

B. Phonatory Measures

1. Physiological Frequency Range of Phonation (PFRP)--Measurement of the lowest tone to the highest tone physiologically
2. Musical Frequency Range of Phonation (MFRP)--Measurement of the lowest tone to the highest tone musically. Both lower and upper limits must be held for one-two seconds.
3. Maximum Phonation Time (MPT)--Measurement of the maximum time that a subject phonates on /s/ and /z/, and both spoken and sung production on the vowels /ɑ/, /i/, and /u/.

C. Respiratory Measures & Glottal Efficiency

1. Pulmonary Function Testing (PFT)--Measurements which help to determine the ability of the lungs and abdomen to support speech and singing

   a. FVC - forced vital capacity--the total amount of air a subject can expel during the entire exhalation process.

   b. FEV 1.0 - forced expiratory volume--the amount of air expelled during the first second of exhalation.

   c. FEF 25-75%- forced expiratory flow in the 25 - 75% range --the amount of air expelled during the middle of the exhalation.

2. Mean Flow Rate (MFR)--Measurement of laryngeal airflow during phonation on the vowel /ɑ/.

Overview

The remainder of this study comprises four chapters, references, and the appendices. Chapter II contains a review of literature in the areas of voice science and vocal pedagogy. Chapter III includes a detailed description of the procedures. Chapter IV consists of the analysis of data, and chapter V, the summary-discussion, conclusions, implications and recommendations for future research. The appendices contain documents pertinent to the study.

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

Advances in understanding voice science combined with technological advances in voice measurement have allowed the introduction of quantifiable measures to the field of vocal pedagogy. Their application is as essential in voice pedagogy as any other discipline in order to measure outcomes and identify optimal strategies and teaching techniques. A review of voice structure and function and the history of voice science and vocal pedagogy will demonstrate the inevitable convergence of voice science and vocal pedagogy and the appropriateness of objective measures in the vocal studio.

Anatomy and Physiology

The structure of the larynx is comprised of four basic anatomic components: cartilaginous skeleton, intrinsic muscles, extrinsic muscles, and mucosa or soft lining. The first component, the skeleton, has three cartilages of primary importance: the thyroid cartilage, cricoid cartilage, and a pair of arytenoid cartilages. Other skeleton components include the epiglottis, hyoid bone, and corniculate cartilage.

The second component, the intrinsic muscles, runs between the cartilages. The names of these muscles are derived from the corresponding cartilages (e.g. cricoarytenoid = cricoid + arytenoid cartilages). The pair of intrinsic muscles that form the bodies of the vocal folds are the thyroarytenoid (TA), or vocalis, muscles. This pair extend from the arytenoid cartilage to a point inside the thyroid cartilage, just below the Adam's apple.

Intrinsic muscles can change the position of the cartilages and pull them through a range of motions . This in turn alters the shape, position and tension of the vocal folds. Different intrinsic muscles have the job of either abducting (pulling apart) or adducting (bringing together) the vocal folds. The principal muscle of abduction is the posterior cricoarytenoid (PCA). The principal muscles of adduction include the thyroarytenoid (TA), lateral cricoarytenoid (LCA), interarytenoid (IA), and cricothyroid (CT). The principal muscle for longitudinal tension, or stretching, is the cricothyroid which participates in pitch control for the singer. The recurrent and superior laryngeal nerves control most of the intrinsic muscles in the larynx. The responsibility of the superior laryngeal nerve is to innervate the cricothyroid muscle (stretching longitudinally), while the recurrent laryngeal nerve innervates all of the other intrinsic muscles (thyroarytenoid or vocalis, posterior cricoarytenoid, lateral cricoarytenoid, and interarytenoid or arytenoideus).

The third component of the larynx, the extrinsic muscles, connects the cartilages to other throat structures, and they raise and lower the laryngeal skeleton. These muscles are commonly known as the strap muscles of the neck and are divided into those below the hyoid bone (infrahyoid muscles), and those above the hyoid bone (suprahyoid muscles). The infrahyoid muscles include the thyrohyoid, sternothyroid, sternohyoid, and the omohyoid. The suprahyoid muscles include the digastric, mylohyoid, geniohyoid, and stylohyoid (Sataloff, 1991).

The mucosa, or smooth lubricated surface, is the final component. The tissues lining the larynx are much more complex than was understood originally. In 1975, physician Minoru Hirano of Kurume, Japan, made important discoveries which revolutionized the understanding and treatment of the vocal folds. He identified five distinct tissue layers in the structure of the vocal fold: a thin,

lubricated epithelium, three layers of tissue called the lamina propria (superficial, intermediate and deep layers), and the deep muscle layer, that of the thyroarytenoid. In practical terms these five layers can be discussed as three basic layers including a cover (epithelium and superficial lamina propria), transition layer (intermediate and deep lamina propria layers), and body (thyroarytenoid or vocalis muscle) (Sataloff, 1992).

Before discussing the physiology of sound, one must examine the power source for the voice. The power source, or infraglottic vocal tract, includes the lungs, rib cage and abdominal, back and chest muscles. This source is responsible for maintaining a controlled airstream between the vocal folds and is constantly working to keep a balance of pressure while the resistance changes as the glottis opens and closes. This balance is critical for allowing the singer to maintain a steady vocal quality. Most often, singers refer to the complex power source primarily as their "support " (Sataloff, 1992). The anatomy of the power source is not thoroughly understood, although many vocal pedagogues and singers freely use terms such as "diaphragm" and often mean different things. In a study by Hixon and Watson (1991) subjects were asked to describe their respiration for singing. They found a striking discrepancy between how subjects thought they breathed and how they actually breathed during singing. The researchers state that a singer who has an accurate concept of respiratory function during singing would most likely be in a better position to use the respiratory system more effectively in performance. Therefore, the anatomy of the power source warrants some examination.

Inspiration, or inhalation is usually an active process. The primary muscles of inhalation are the diaphragm and the external intercostal muscles. The diaphragm is an inverted double dome shaped structure of muscle and tendon which separates the thorax (chest) from the abdomen (belly). The

diaphragm is a muscle capable of delivering only inspiratory force and is located inside the rib cage (extends along the bottom of the rib cage). The external intercostal muscles are located between the ribs. Upon inhalation the diaphragm is pulled downward and flattens, and its descent causes air to enter the lungs. Because the diaphragm is located inside the rib cage, it is impossible to put one's hands on the abdomen and feel the diaphragm. When hands are placed on the abdomen the muscles felt contracting are referred to collectively as the abdominal muscles. These muscles include the rectus abdominis, transversus abdominis, and the internal and external obliques, and are usually regarded as the most important muscles of active expiration, or exhalation (Radionoff, 1994). However, the internal intercostals and other chest and back muscles including the transversus thoracis, subcostals, quadratus lumborum, and the latissimus dorsi also contribute (Bunch, 1993). Therefore, during active exhalation, muscles may either raise the pressure within the abdomen and force the diaphragm upward, or they may lower the ribs and sternum to decrease the dimensions of the thorax (Sataloff, 1992).

The production of sound originates in the cerebral cortex of the brain. The notion of vocalization is sent to the precentral gyrus in the motor cortex, which transmits another set of instructions to motor nuclei in the brainstem and spinal cord. These areas in turn send out the necessary messages for coordinating the activities of the larynx, the thoracic and abdominal musculature, and the vocal-tract articulators.

At the onset of sound the vocal folds are in contact and the glottis is closed. However, as the lungs expel air, pressure below the glottis builds and progressively drives the vocal folds apart. The vocal folds open from the bottom up, until the glottis is open and air begins to flow. This flow of air produces a Bernoulli effect (known as the myoelastic aerodynamic theory) which tends to

pull the vocal folds shut. This occurs because of a reduction in the lateral air pressure caused by its forward motion as well as the elastic properties of the vocal fold tissues. Also the pressure of the airstream below the glottis diminishes as the glottis opens to let the air out (Sataloff, 1992).

The vocal folds were previously commonly called vocal cords. In order to be more precise, the scientific community renamed these structures according to the way they function. The vocal folds do not excite the air by vibrating like violin strings, rather they create puffs of air in the vocal tract by the opening and closing of the glottis. The number of times per second that the vocal folds separate and collide determines the number of air puffs that escape (number of occurrences, or frequency). The frequency of the vocal fold opening and closing is perceived as pitch and is measured in Hertz (e.g. middle C is approximately 262 Hz). The sound produced at the vocal fold level is a only a buzz; however, this sound contains a fundamental frequency with a complete set of harmonics or overtones. The sound then passes from the larynx through the supraglottic vocal tract which acts as a resonator and enhances various harmonics. The harmonics that become strengthened depend on the shape of the vocal tract which is determined by vowel production and the desired timbre or sound quality. The harmonics which become strengthened as they pass through the resonator are called formant frequencies. Johann Sundberg of the Royal Institute of Technology in Stockholm has demonstrated that there are four or five important resonance frequencies (formants) in the human voice. The formant which has received the most notoriety in the singing world is known as the "singer's formant" and ranges approximately between 2400 and 3200 Hz depending on the voice category. Sundberg states that the main acoustical contribution in generating the singer's formant comes from a clustering of the third, fourth, and fifth formants. Because there is only a small separation between these sung frequencies, "the sound

transfer ability of the vocal tract in the frequency range of these formants will increase, and a spectrum envelope peak will arise, other things being equal" (Sundberg, p. 119, 1987). Sundberg further states that the singer's formant is also dependent on the amplitudes of corresponding voice source partials.

Voice Science

Though important pedagogical writings about the voice can be traced to the 1700's, scientific writings about the voice date back centuries earlier. In fact, the cultural history of the larynx and voice dates back to more than 2,000 years before the birth of Christ. Hans von Leden, eminent laryngologist and father of phonosurgery, describes four cultural phases that the concept of voice production passed through: stage one the fictitious or mythical stage, stage two the metaphysical stage, stage three the traditional stage, and stage four the realistic stage (von Leden, 1993).

In the first, or fictitious, stage man explained natural phenomena as magical, religious, or supernatural events. The physician was considered to be a god or priest. Illness was often ascribed to demons. In ancient Babylon, the demon Namtary was credited for causing throat ailments, while in Egypt Isis was worshipped as the healing goddess. There is also among the hieroglyphs on one of the tombstones erected for King Aha at Sakkara a picture of a kneeling person with pointed instrument directed at the person's throat, and this is from about 2900 B.C. Also in ancient Greece most gods in the pantheon had some association with health: Asclepios was the principal god of healing, but his entire family was associated with health (von Leden, 1993).

In the second, or metaphysical, stage knowledge was based partly on observation, but mainly on speculation. The doctor of this stage considered himself a philosopher. Two of the most well known philosophers during this stage

were Hippocrates and Aristotle: However, the most outstanding example was Claudius Galen. von Leden (1993) states that Galen was probably the most influential medical author of all time, as well as being the founder of laryngology and the godfather of phoniatrics and voice science (von Leden, 1993).

In the third, or traditional, stage all information was based on tradition or revelation, on the great authorities of the ancient world, and on the Fathers of the Church. Medicine was the storehouse for ancient wisdom throughout the early Christian era, the age of Arab medicine, and the age of Scholasticism. Great healers of this stage include Christ, St. Luke, and St. Blaise. Important credence to the performing arts was given by patron Pope Gregory I and famous paintings depicted the eloquence of voice. Similar representation of the voice occurred in different cultures such as a painting by Raphael, a rendering from the Middle East, and a Native American work of art. The scholastics of this stage believed that the great authorities of the ancient world had the answers to all medical questions. Those considered the greatest physicians and scientists of all time were Galen, Hippocrates, and Aristotle. During this stage there was a great anatomist named Mondino de Luzzi (1275 - 1327) of Cologne. However, Galen was still considered correct even if there was a discrepancy between his book and the live dissections by de Luzzi (von Leden, 1993).

In the fourth, or realistic, stage knowledge was based on actual observation, experimentation, and coordination. This stage was the beginning of medical science where physicians were expected to become proficient in both art and science. The beginning of this final stage parallels the explosion of scientific knowledge during the Renaissance. There were many anatomy professors during this stage: However one person must be given credit for being the pioneer of this era. Leonardo da Vinci (1452-1519) contributed new and important information to the anatomy, physiology, and pathology of the human voice. Other important

anatomy professors and authors of texts include Andreas Vesalius (1514-1565), Gabriele Fallopio (1523-1563), Bartolomeus Eustachius (1520 - 1574), Hieronymus Fabricius ab Aquapendente (1537-1619), Caspar Bauhinus (1550-1624), Julius Casserius (1561-1616), Claude Perrault (1613-1688), Thomas Willis (1621-1675), Dennis Dodart (1634-1707), and Giandomenico Santorini (1681-1737) (von Leden, 1993).

It must be noted at this point that early in the 18th century, Giovanni Battista Morgagni (1682-1771) was so influential in the field that he should be considered the second founder of laryngology. He clearly demonstrated that the larynx is the site of disease and that changes in function are related to pathologic changes. Further important contributors include Antoine Ferrin (1693-1769) and Albrecht von Haller (1708-1777) (von Leden, 1993).

In the 19th century many important discoveries were made that helped to facilitate better understanding of the voice. The interior of a human larynx was observed for the first time (Francois Magendie 1783-1855), sound was described as arising from a series of puffs (Jean Baptiste Biot 1774-1862), the vibration of falsetto tones was examined (Carl Lehfeldt 1835), and the speech center of the brain was described (Pierre Paul Broca 1824-1880). Two other major contributors include the outstanding physiologist Johannes Müller (1801-1858), who proclaimed the myo-elastic theory of phonation in 1839, and Hermann von Helmholz (1821-1894), who pioneered the acoustics of sound (von Leden, 1993). One final important contributor to the field of laryngology and voice science, Spaniard Manuel Garcia II (1805-1906), merits some discussion. However, before a discussion of Garcia's contribution can ensue, it is necessary to give a brief account of some attempts at viewing the larynx prior to Garcia.

In 1807, Dr. Bozzini of Frankfort-on-the-Main invented and attempted to use the first device for laryngeal examination; however his results were

insignificant. Twenty years later, Dr. Senn of Geneva constructed a small mirror but had no means of illumination. He failed at his attempt to view the vocal folds; however, he attributed the failure to the smallness of the mirror. At a meeting in 1829 Dr. Benjamin Babington of London submitted an instrument called a glottiscope which was much like the ordinary guttural mirror used today. However, it additionally had a curved spatula for depressing the tongue. The first attempt at auto-laryngoscopy was by M. Cagniard de la Tour in 1829; however, he was only partly successful. Even as late as 1832 many medical professionals doubted the effective use of a mirror for examining the larynx. Another citation of using a mirror to aid in laryngeal examination can be found in a book entitled *Practical Surgery* by Robert Liston in 1837. Moore (1991) states that one of the main problems of these investigations was insufficient light into the larynx for adequate viewing. Attempts at rectifying this problem were made by Adam Warden and by a Mr. Avery of London in 1844. These events bring us to the name that is most likely one of the best known in the history of laryngoscopy: Manuel Garcia II.

Singing teacher Manuel Garcia II was the first to effectively use the laryngeal mirror for routine visualization of the larynx. Moore states that Garcia "should be given credit for his original thinking" since he was most likely unaware of previous work in this area (1991, p. 267). In 1854 Garcia bought a dentist's mirror from the surgical instrument maker Charriére for 6 francs. This particular mirror had been dismissed as of no import at the London Exhibition in 1851. When he returned home, he placed the dental mirror against his uvula while holding another mirror in his hand onto which flashed a ray of sunlight. With these two mirrors and sunlight, he was able to observe his vocal folds in action. He wrote a description of what he saw and presented his paper titled "Physiological Observations of the Human Voice" to the Royal Society of London

in 1855. As far as Garcia was concerned, he had proven his theories and that the viewing of the vocal cords with a laryngoscope ceased to be of any special use. His findings were initially received with indifference by the medical profession, and it was two years before the medical field realized the importance of the instrument (Mackinlay, 1908). Garcia's contribution is evident not only in the general fields of laryngology and voice science, but also within a new sub-specialization. The evolution of this new specialized field, that of "arts medicine," can be traced to the era of Manuel Garcia II (Sataloff, 1991).

Instrumentation

It is necessary to monitor sound production and sound in order to assess and identify optimal strategies of vocal technique. The method that the old master teachers used was that of subjectively listening and watching (Miller, 1993). Although subjective measures are useful, not every singer processes information in the same way. Some singers may learn by imagery, while others may need intellectual concepts. Still other singers would benefit by the use of other senses, in particular the visual sense. Today because of innovators such as Helmholtz and Fourier, we are able to see the creation of acoustical sound while it is being produced.

Hermann Von Helmholtz (1821-1894), a Professor of Physiology in Heidelberg, pioneered the acoustics of sound. In 1877 Helmholz carried out a thorough investigation of the timbre of steady tones. By using electrically driven tuning forks and tuned resonators (now called Helmholtz resonators), he demonstrated that the sounds of most musical instruments (including vocal folds) consist of a series of harmonics that determine the timbre. These studies were so thorough that very little significant new information appeared in the literature until approximately 1950 (Rossing, 1982). Another important figure in the

evolution of the measurement of sound was mathematician Joseph Fourier (1768-1830) who formulated an important mathematical theorem. When this theorem is applied to determining the harmonic components of a periodic waveform, it is called "Fourier Analysis." The terms *spectrum analysis, harmonic analysis,* and *sound analysis* are sometimes used to describe Fourier analysis applied to sound (Rossing, 1982). The pioneering work of individuals such as Helmholz and Fourier has led to objective measurement of sound through instrumentation.

A foundational basis for the scientific assessment of voice production has been developed during the past 10 years. A major portion of the current data collected, as well as the type of measure, and the type of equipment used in the data collection and analysis, applies clinically to the speaking voice. These objective measures enable the study of various physical, emotional and mental conditions of the voice (Gould, 1991). Objective measures are becoming more prevalent as the number of clinical voice laboratories increases. A review of literature reveals that acoustic, aerodynamic, and phonatory function measures are widely accepted in clinical voice laboratories, although there is no formal standardization (Gould, 1987; Sataloff, 1990; Hirano, 1991; and Hicks, 1991). A conference was held in Bethesda, Maryland, in 1990 to discuss assessment procedures and objective measurements of speech and voice function.

Procedural standards need to be developed for the assessment of voice disorders in order to eliminate duplications between various acoustic, glottographic, and aerodynamic measurements. Titze states that multiple levels of observation should be abolished because "redundancy in measures can complicate procedures, drive up the cost of experimentation, and mystify rather than enlighten the process of assessment. . . . Removal of unnecessary clinical and experimental baggage is therefore a high priority" (Titze, 1991, pgs. 43 & 44). The problem of non-standardization in regard to acoustic perturbation is

demonstrated in a table by Titze. Sixteen types of perturbation measures are outlined, each of which measures similar intercycle fluctuation in fundamental frequency. However, the mathematical definitions differ. This causes difficulty in the comparison of results which have been obtained by independent investigators in relation to similar subject populations. Titze asks two important questions: "What relationships exist between these acoustic measures," and "How predictable is one from the other?" (Titze, 1991, p. 44). Titze further asserts that a large number of subjects is needed to establish norms and variability among subjects.

In regard to standardization, the preface in Hirano's book Clinical examination of voice (1981) is informative from a clinical standpoint, but it is also instructional for the purpose of vocal pedagogy (Titze, 1991). Hirano's preface is as follows:

> "In the field of otology and audiology, several techniques for the clinical examination of auditory function have been established and standardized. As a result of the standardization of these techniques, it is possible to compare the auditory function of different subjects examined at different places and/or different occasions and to monitor the results of treatments in a reliable manner. With regard to phonation, various methods have been proposed and used by many clinicians and researchers all over the world. Unfortunately, none of these methods appears to be standardized on an international basis" (Hirano, 1981, preface).

Similar statements were made at conferences in 1981 by Ludlow, O'Connell and Hart, and in 1986 by Fritzell and Fant (Titze, 1991).

The current representative "Lone Ranger" approach to vocal assessment is a result of the lack of standardization. The U.S. lags behind the international community in regard to standardization. Hicks (1991) lists several potential causes: (a) complacency, (b) skepticism, (c) paranoia, (d) philosophical

disagreement, (e) time, and (f) finances. Why is it necessary to standardize? Standardization is needed so that (a) results are interpretable and generalizable, (b) norms are representative and usable, (c) results are both reliable and valid and (d) performance variability can be determined between true performance differences and protocol-created differences (Hicks, 1991).

Standardization can be achieved in various ways: (a) by use of the same technology, (b) by identification of measures most appropriate for consistency, or (c) by systematization of the procedures and tasks. Some researchers express fear that standardization may limit flexibility. However, Kent states "if nothing is standardized, then the clinical interpretation is essentially impressionistic in its substance" (Kent, 1991 p. 212). Another expressed fear is that it may entail highly prescribed test sequences. According to Kent, the question concerning standardization may not be, "should standardization be attempted?" but rather, "when should standardization begin?" and perhaps, "what body or agency should undertake the standardization task?" (Kent, 1991, p. 213).

To have standardization, clinical tests will need to meet certain criteria. These tests must provide clinically useful information which can be utilized in the determination and adjustment of the treatment plan for patients (Hirano, 1991). The importance of standardization applies not only to clinical voice use, but to the emerging use of voice laboratories in music schools such as the *Otto B. Schoepfle Vocal Arts laboratory* at the Oberlin College Conservatory of Music directed by Professor Richard Miller. Hirano's criteria applied to acoustic and aerodynamic measures in the vocal arts lab can be written as follows: objective measures must produce pedagogically useful information which can be utilized in the determination and adjustment of the voice study plan for students.

Objective Measures

Published Norms

Although no standardization of objective measures is presently available, there are published normative data which are widely accepted. Three major clinical sources for charted data are (a) Clinical measurement of speech and voice (Baken, 1987), (b) Clinical examination of voice (Hirano, 1981), and (c) Readings in clinical spectrography of speech (Baken & Daniloff, eds., 1991).

In Clinical measurement of speech and voice (1987), a table outlines the Speaking Fundamental Frequency (SFF) of Normal Caucasian Adults. The columns of the table consist of (a) subject age (mean & range), (b) number of subjects, (c) mean SFF (Hertz, semitones & range), (d) median SFF (Hertz, semitones, & SD+semitones), (e) total range (semitones), (f) 90% range (semitones, and (g) source. The table also divides the male and female populations. Thirteen sources by researchers dating from 1942 - 1981 contain collected data from spontaneous speech or reading passages. Nine of the 13 sources use selected portions of the "Rainbow Passage." Charts for the SFF of children are also available. In research at the American Institute for Voice and Ear Research (AIVER), Sataloff uses normative data for the SFF published by Baken (1987) for males by (a) Hollien and Jackson (1973), and (b) Hollien and Shipp (1972), and for females by (a) Stoicheff (1981), and (b) McGlone and Hollien (1963).

Another table available, containing five sources dating from 1965-1971, records the Maximum Phonational Frequency Range (MPFR) of adults, again divided into male and female populations. In research at AIVER, Sataloff uses the normative data by Hollien, Dew and Phillips (1971). Currently, there are no widely accepted normative data in regard to the Musical Frequency Range of Phonation. Other acoustic normative data used by Sataloff at AIVER, include (a)

Relative Average Perturbation (RAP) by Takahashi and Koike (1975) and (b) Jitter Ratio (JR) by Ludlow, Coulter and Gentges (1983).

In regard to Mean Flow Rate (MFR) and Maximum Phonation Time (MPT), Hirano's 1981 publication, Clinical examination of voice, contains widely accepted norms. Hirano outlines normal values for mean flow rate in milliliters per second in adults. There are five sources dating from 1964 - 1977. In research at AIVER, Sataloff uses the normative data by Hirano (1968). MFR's are charted for children with normal and pathological states as well. Hirano also outlines normal values for Maximum Phonation Time in seconds for adults, including nine sources dating from 1940 - 1977. MPT is available for children with normal and pathological states as well. In research at AIVER, Sataloff uses the normative data by Hirano (1968).

According to Kent, in the foreword of Baken and Daniloff's publication, Readings in clinical spectrography of speech, (1991), the current sound spectrograph has only recently become heralded as the most productive analysis instrument used in the speech laboratory. Its prominent standing stems from its ability to display the rapidly changing spectral properties of speech. The applications of this instrument are far from exhausted. In this publication, Baken and Daniloff present a collection of papers which discuss (a) what spectrography is, (b) the accuracy and limitations of Sona-Graph measurements, (c) spectrograpic characteristics of normal speech, (d) speech sound development and (e) the use of spectrography in evaluation and therapy.

There are also published normative data for respiratory function measures including the measures of (a) forced expiratory volume (FEV 1.0), (b) forced vital capacity (FVC), and (c) forced expiratory flow from 25-75% of the expiratory volume (FEF 25-75%). These data contain studies by Schorr-Lesnick (1985),

Morris (1971), and Knudson (1976) AIVER uses normative data by Knudson (1976).

In the clinical voice laboratory, acoustic analysis and respiratory function are the two major divisions. In the past decade, there has been a vast growth in the number of voice laboratories. Out of this growth, has come a need for consumer information in regard to buying the most appropriate equipment for a desired application.

In a study by Read, Buder and Kent (1992), seven marketed and three recently introduced systems for acoustic speech analysis are evaluated. According to Read et al., at least 15 systems are currently available to the consumer. The reviewed performance characteristics of the seven marketed systems include (a) system components, (b) basic capabilities, (c) documentation, (d) user interface, (e) data formats and journaling, (f) speed and precision of spectral analysis, and (g) speed and precision of fundamental frequency analysis. Evaluation of basic capabilities are also compiled for the three recently introduced systems.

The seven marketed systems include (a) "See Speech" (CSpeech), (b) Canadian Speech Research Environment (CSRE), (c) DSP Sona-Graph Model 5500, (d) Interactive Laboratory System (ILS-PC), (e) MacSpeech Lab II, version 1.7, (f) Micro Speech Lab (MSL), and (g) Signalize, version 1.2. The three recent systems include (a) Sensimetrics Speech Station, (b) the Kay Elemetrics Computerized Speech Lab (CSL), and (c) the LSI Speech Workstation.

In examining basic capabilities, Read et al. (1992) have divided the systems into three categories; those which are IBM compatibles, those which operate on Macintosh computers and those which are dedicated devices. Read et al. state that the largest number of alternative systems is currently available for IBM PC/AT compatibles. The researchers discuss important considerations when

choosing a system which best meets the users' needs. When choosing a speech analysis system, a purchaser must bear in mind the specific application: (a) teaching, (b) research, (c) clinical, or (d) a combination. Read et al. (1992) stated that the prospective user should also think about both current and future needs. Other considerations are (a) the need for networking, (b) purchase and installation, (c) manuals, (d) technical support, (e) user interface, (f) efficiency, and (g) cost.

In this study, the researchers also pointed out the importance of the compatibility of data formats, data journaling and spectral analysis. The issue of standardization is once again of paramount importance. Read et al. (1992) asserted that

> there is a clear need to standardize file headers to facilitate data among systems. . . . Likewise, there is a need to standardize measures of speech and voice. . . at the very least, speech analysis systems should come with clear documentation of the algorithms used in deriving acoustic measures (Read et al., 1992, P. 330).

Read et al., however, stated that a paradoxical way to promote standardization is to make more than one means of analysis available. Perhaps, by doing so, users may reach a consensus after comparing performances. Five years before this study, Gould (1987) outlined the idea of a voice analysis network in which laboratories could tie into a central computer.

According to Sataloff, Spiegel, Carroll, Darby, Hawkshaw, and Rulnick (1990), Visi-pitch, which interfaces with an IBM-PC, appears to be the most widely used instrument for acoustic analysis in the United States. Sataloff et al. stated that it is an extremely good, reasonably priced, durable, instrument. Another instrument for acoustic analysis is the PM Pitch Analyzer which is useful for longer samples. However, the tape recorder is still a highly valuable and essential

tool for acoustic analysis (Sataloff, Spiegel, Carroll, Darby, Hawkshaw, and Rulnick, 1991).

The validity and reliability of analysis depends on using controlled, repeatable circumstances in the recording of patients' voices (Sataloff, et al., 1991). Since the intensity of sound decreases in proportion to the square of the distance from the sound source, microphone placement is critical. At the American Institute for Voice and Ear Research, Sataloff et al. use a Hohner International harmonica holder to keep the microphone consistently at a 6-inch distance from the mouth for all recordings. A Beyer unidirectional microphone is used and data are recorded on a Nagra E reel-to-reel tape recorder at 7 1/2 inches/sec. Sataloff et al. further stated that this method for consistent microphone placement does involve compromise. However, it has been found more satisfactory than other methods which also involve compromise. Sataloff (1991) stated that ideally, in the near future, the process of acoustic analysis will be measured by one simple, inexpensive instrument equivalent to an audiometer.

Today, we are now closer than ever before to reaching Sataloff's ideal for acoustic analysis. Kay Elemetrics, the manufacturers of the DSP Sona-Graph, are now producing the Computer Speech Lab (CSL) with options such as the Visi-pitch 2 (VP2), Sona-Match (SNM), and the Multi-Dimensional Voice Program (MDVP). Although MDVP is now an option available with CSL, the history of the CSL and MDVP are very different, with the converging point being the manufacturer Kay Elemetrics.

The immediate predecessor of the CSL was the Sona-Graph, specifically the DSP 5500 signal processing center which was developed in the early 1980's. This instrument was the first completely digital real time spectrogram developed solely by Kay Elemetrics. Until the 1970's, the Sona-Graph was completely analog. Then the research and development department at Kay Elemetrics began to use digital

methods which immensely improved the instrument. After the classic Sona-Graph, some hybrids were developed including the 7800 Sona-Graph (the first attempt at a digital Sona-Graph) and finally the predecessor of the CSL, the DSP 5500. In the late 1980's technology supported the development of a PC-based system, with its obvious advantage of lower cost and wider availability. Thus was the beginning of the CSL at Kay Elemetrics. At first, both the software and hardware were developed at Kay; however, the software was completed at Speech Technology Research (STR) in Canada (which became the standard of the current CSL). The first version of the CSL became available in 1989. The current version, however, has expanded capabilities with more options for application such the MDVP (Deliyski, personal communication 1996).

The concept for the MDVP was derived from a dissertation by Demitir Deliyski. In 1984 Deliyski was working at the Academy of Science in the Institute of Industrial Cybernetics and Robotics as well as the Medical Academy Department of Phoniatrics researching pathological voices in Bulgaria. When Deliyski began his dissertation, he was looking for other parameters that described the voice. What grew out of this need for better diagnostics became the MDVP. The software and hardware were both initially developed by Deliyski. In 1991 while holding a post doctoral faculty position at Memphis State University Speech and Hearing Center, Deliyski began to work on an industrial design for making the product available for manufacturing. By the end of 1991, he began to discuss the possibility of converting his software and hardware to the CSL hardware. In 1992 he merged with Kay Elemetrics and developed the current hardware and software systems. The first sales of the MDVP were in April of 1993. The rationale for the MDVP was developed in Bulgaria, the methods were perfected in Memphis, and the final development took place at Kay Elemetrics (Deliyski, personal communication 1996).

A variety of instruments are available to the consumer for measuring respiratory function. It is now possible to obtain realistic dynamic respiratory data useful for feedback purposes about the degree of synchrony, or lack of it, between respiratory effort and phonatory result (Boone, 1991). In a table Boone alphabetically lists available instrumentation including (a) Electromyograph, (b) Magnetometers, (c) Manometers, (d) Phonation Function Analyzer, (e) Pneumotachometers, (f) Pressure transducers, and (e) Spirometers. This instrumentation can be divided into four categories in regard to basic capabilities; those which operate on IBM PC/AT compatibles, those which operate on Macintosh computers, those which operate by remote, and those which are dedicated devices, some of which are easily portable. As with the acoustic analysis instrumentation, there is not one standard way of measuring respiratory function.

The clinical voice laboratory provides the vocal pedagogue who is interested in voice science with essential information for modeling. The current prototype for a vocal arts laboratory is the Otto B. Schoepfle laboratory run by Professor Richard Miller at the Oberlin College Conservatory of Music. According to Miller (1993), the heart of the laboratory is the Kay Elemetrics DSP 5500 Sona-Graph. The lab is equipped to analyze live or prerecorded signals by using (a) an on-line microphone, (b) cassettes, (c) CD's, (d) records, (e) video tapes, and (f) DAT. Prerecorded signals are entered into the Sona-Graph by the use of an amplifier. Other instrumentation includes a nasometer, which measures the degree of nasality of sound, and a laryngograph, which measures the closing and opening of the glottis during phonation. The laboratory is used for both pedagogical and research purposes.

Acoustic Measures

In a study by Heuer, Sataloff, Carroll, Radionoff, Spiegel, and Rulnick (1991), acoustic measures were collected from classically trained singers whose larynges were normal or had signs of reflux. Data on singers with reflux were included, since reflux is common among classical singers and does not significantly alter these measures. Heuer et al., stated that normative values must be established in order for acoustic measures to be of clinical value. The researchers also asserted that most previous reports have studied only speakers without formal training in speech or singing. As a result, there is a question as to the appropriateness of using such norms when one is evaluating trained singers. Thus, this study was designed to investigate the acoustic parameters in normal, healthy, classically trained singers and to compare their normative value with previously established norms for untrained voice users.

The subjects of this study were 79 classically trained singers with a minimum of three years of training. The singers included 42 females between the ages of 18-54 years and 37 males between the ages of 22-63 years. All 79 subjects performed a standard sample of tasks consisting of being asked to (a) state name, date and age (conversational sample), (b) produce physiological range, (c) produce musical range, (d) prolong spoken vowels on /ɑ/, /i/, and /u/, (e) prolong sung vowels on /ɑ/, /i/, and /u/, (f) produce a spoken and sung /ɑ/ at the same pitch and (g) read the Marvin Williams and Towne-Heuer Reading Passages.

Samples were obtained by using a Beyer dynamic unidirectional microphone, attached to a Hohner harmonica holder keeping a consistent mouth to microphone distance, and a fourcin laryngograph. The audio samples were recorded on a reel-to-reel Nagra E tape recorder and stored on audiotape for analysis by the Kay Visipitch and PM Speech analyzer. Glottographic data and

acoustic samples were fed directly into the Kay DSP Sona-Graph for analysis using the voicing parameters program.

Means and standard deviations were obtained for measures of fundamental frequency (F_O), perturbation (Jitter and Shimmer), harmonic-to-noise ratio, and loudness derived from the three instruments which are described and compared with other normative data. There were five variables not controlled for in this study: (a) subjects were free to select pitch, (b) no control over the amount of sleep prior to the evaluation, (c) no control of "warm up" prior to the test, (d) no control over performance or singing the previous evening or on the day of the test and (e) no control of menstrual cycle time. Heuer et al., stated that these variables have rarely been controlled in previous studies, and that it is seldom practical to control all of them in a clinical setting.

No statistically significant differences were found between speaking F_O estimates and reading F_O estimates. Heuer et al., stated that means were slightly lower for speaking than reading as postulated by Ramig and Ringel (1983) but not to a statistically significant degree. Physiological ranges were obtained and analyzed on the visipitch. The obtained physiological ranges were found to be similar to those reported in Baken (1987).

The singing F_O was obtained for the male and female singers. Both groups in this study chose to sing at a higher pitch than the spoken pitch. The researchers found these differences to be statistically significant at $p = < .05$ for both methods of estimate and for both sexes. Musical ranges were obtained and analyzed on the visipitch. The musical ranges obtained by Heuer et al. were smaller than those reported by Brown, Morris, Hicks, and Howell (1991). The authors stated that a possible explanation is the large proportion of young singers in their sample, as compared to well-seasoned professionals used by Brown et al.

Jitter was measured by the Sona-Graph parameters program which uses the Davis formula for Relative Average Perturbation (RAP). Heuer et al., found the jitter during sung vowels to be much more variable both between and within groups, and particularly for female singers. They stated that this difference was possibly related to the use of laryngeal movement to assist in vibrato which shifts the position of the larynx and causes inaccuracies in data collection.

Shimmer was measured using the Sona-Graph parameters program. It was more stable than jitter in the same group of subjects. Harmonic to noise (H/N) ratios were also obtained using the Sona-Graph voicing parameters program. One Way ANOVAs found no significant difference between the H/N ratios within the male group, while there was a significant difference within the female group. Heuer et al. stated that the trend was toward better H/N ratios for female singers.

This study concluded that fundamental frequency estimates for both male and female singers were similar to those summarized in Baken (1987) and Colton and Casper (1990). Also, the data are comparable to those of Brown et al. (1991) for female singers but for males were similar to those of the Brown et al. untrained population. The authors stated that the physiological range data was within one semitone of previous estimates. Obtained jitter measures were lower than those reported for normal speakers in Baken (1987) and Colton and Casper (1990). Obtained shimmer measures differed from those reported in Baken (1987) and repeated in Colton and Casper (1990). Shimmer was slightly lower in males, and shimmer was slightly more elevated than previously documented in females.

According to Heuer et al., perturbation measures during singing appear to be contaminated by methodology and instrumental errors. The researchers further stated that the use of the glottograph may produce inherent errors. Heuer et al. stated that acoustic parameters of these singers measured from speaking

acts are very similar to speaking norms published in literature. However, measures of jitter, shimmer and H/N as shown by the Kay Sona-Graph during singing may be more variable than speaking task values. The authors stated that these differences suggest a relationship to poor technique, inherent differences with the instrumentation and methodological problems, as well as inherent differences between singing and speaking.

Respiratory Measures

In a study by Carroll, Sataloff, Heuer, Spiegel, Radionoff, and Cohn (1991), respiratory measures were collected from classically trained singers whose larynges were normal or had signs of gastroesophageal reflux disease (GERD). Data on singers with reflux were included, since reflux is common among classical singers. Carroll et al. stated that classically trained singers are the professional athletes of the voice world. They further asserted that studies of maximum phonation times and mean flow rates with a significant number of professional singers have not been well reported. The researchers also stated that adequate breath management is essential for singers, thus there is a need for pulmonary function testing.

The subjects for this study were 40 classically trained singers. The singers included 20 males with an average age of 27 years and 20 females with an average age of 25 years. All subjects were active classical solo singers with a minimum of seven years of formal classical training who had been diagnosed by otolaryngologic evaluation at the time of assessment with no laryngeal abnormalities with an exception of reflux. Carroll et al. reported that no significant difference was found between patients with or without reflux.

The instrumentation required for Maximum Phonation Time (MPT) was a hand-held stopwatch, accurate to 1/100 of a second. Mean Flow Rate (MFR) was

computed with a Tamarac Systems "Presto" spirometer which operated with a pneumotach or the S & M Instruments Pulmoscreen Spirometer. Pulmonary Function Testing (PFT) was obtained with the "presto" spirometer or the Infomed Corporation Remote Field Unit Spirometer. The spirometers were calibrated daily and were equipped with a 1 1/2 inch diameter transducer hose. Both spirometers computed the observed, predicted and percent predicted of the reported pulmonary functions and used the Knudson 1976 normative data.

All 40 subjects performed a standard sample of tasks which included (a) maximum phonation times (b) mean flow rate and (c) pulmonary function testing. MPT measures reported on a subset of 18 subjects. Each subject was instructed to "take a big breath" and sustain the spoken or sung vowel for "as long as you can." For MFR measures, subjects were instructed to phonate on /ɑ/ into a spirometer "at a comfortable pitch and loudness" for as long as comfortably possible, without maximum duration. This instruction was necessary for preventing skewed results. Each subject wore noseclips while phonating /ɑ/ with his mouth around the spirometer mouthpiece. For PFT measures, subjects again wore nose clips and were coached throughout the testing by the examiners to gain the best possible effort.

Carroll et al. stated that the mean MPT results of males were comparable to results of Ptacek and Sander (1963), while the results of the females MPT were lower than the findings by Hirano (1968) but comparable to those of Sawashima (1966) and Yanagihara (1966), Ptacek and Sander (1963), and Shigemori (1977). It must be noted, however, that this study was limited to normal classically trained singers. The researchers stated that the mean maximum duration time for /s/ was borderline high compared to previously published data. Carroll et al. found the MFR measures to be higher than those published by previous studies. The researchers suggest that a possible explanation of the differences in

measurement may be a learned behavior. This learned behavior may be a general tendency to reduce possible hyperfunctional activity during sustained phonation tasks.

The PFT measures for this study were limited to FEV 1.0 (forced expiratory volume during 1 second), FVC (forced vital capacity), and FEF 25-75% (forced expiratory flow from 25-75% of the forced expiratory volume). Three male subjects were unable to meet the repeatablility criteria. Male subjects averaged 103% of predicted for FEV 1.0, whereas females averaged 106% of predicted. Males averaged 100% of predicted for FVC, whereas females averaged 105% of predicted for FEV 1.0 . Males averaged 94% of predicted for FEF 25-75%, whereas females averaged 91% of predicted. Out of the 40 subjects, 25% (N=10) had mid-flow values (FEF 25-27%) less than 80% of predicted, with the lowest being 51% of predicted. Carroll et al. stated that none of these subjects had ever smoked cigarettes.

Carroll et al. reported that four subjects were referred to a specialist in treatment of obstructive airway disease who was dually certified in allergy and pulmonary medicine. One was diagnosed with asthma, one had obstructive disease, one had allergies, one had reflux, and three had a combination of two or more airway diseases. Three subjects were treated with bronchodilators. The researchers pointed out that these conditions would have been missed without objective assessment. The problems likely would have been attributed to technical deficits rather than obstructive diseases.

The researchers stated that this study confirms the Schorr-Lesnik et al. (1985) study of professional singers. The Schorr-Lesnik study reported the predicted values of Morris (1971), whereas this study used predicted values by Knudson (1976). Carroll et al. listed several uncontrolled variables. These include (a) no specific avoidance of measures during the morning, (b) no

measures of body fatigue or degree of stress, and (c) no control over menstrual cycle timing.

In conclusion, the study by Carroll et al. revealed (a) average MPT for /ɑ/ less than that of published norms by Hirano, (b) s/z ratio borderline elevated, (c) average MFR were higher than published norms by Shigemori (1977) and Yoshioka (1977), and (d) PFT confirmed the Schorr-Lesnick (1985) study of professional singers. Carroll et al. suggested that previously published data may not be completely appropriate for evaluation of "professional singers," since it would appear that vocal training may produce individuals who manage the interaction between respiration and vocalization in a different manner than non-trained singers. Carroll et al. stated that further research should include having (a) larger populations of classical singers with attention to height, weight and ideal body weight, (b) respiratory performance throughout a 12-hour period, (c) longitudinal studies repeated at a specific time of day, (d) respiratory performance before and after heavy singing, and studies (e) correlated with menstrual cycle changes.

Vocal Pedagogy

Prominent writings on the art, craft and science of the teaching of singing can be traced to the 1700's and represent various methods of teaching singing. In Historical vocal pedagogy classics, Coffin (1989) outlines the methods of prominent pedagogues such as Pier Francesco Tosi, Giambattista Mancini, Manuel Garcia I, Manuel Garcia II, Francesco Lamperti, and Giovanni Battista Lamperti. Included are a number of other early pedagogical methods by Mathilde Marchesi, Julius Stockhausen, Enrico Delle Sedie, Emma Seiler, William Shakespeare, Herbert Witherspoon, William Earl Brown, Margaret Chapman Byers, William Johnstone-Douglas, and Lilli Lehmann. It is interesting to note that Marchesi and

Stockhausen, who became known as great teachers, were students of Manuel Garcia II (Mackinlay, 1908).

One of the most eminent schools of vocal pedagogy is the *bel canto* school, which can be traced from Nicola Porpora (1686-1768) through the Garcia Family. We have no description of what Porpora taught other than the music that he wrote for his students. The first important writing on the teaching of singing was published in 1723 by Tosi (Coffin, 1989). Pilkington asserts that Tosi's Observations on the florid song should be regarded as an early authoritative guide to the late 17th and early 18th century techniques of embellishment and interpretation (Tosi, 1926). Although there are different schools of teaching (Miller, 1977), the influence of the *bel canto* school is evident in the German school of pedagogy through Garcia's teaching of Johanna Wagner (Richard Wagner's niece) and Julius Stockhausen (Mackinlay, 1908).

Reid, who was a prominent pedagogue in the 1950's and 1960's, believed that scientific studies by Garcia and others were partially responsible for the decline of the *bel canto* school and that the information "clouded" tone production (Reid, 1950). Coffin refutes this statement and asserts that "there is no better understanding of the *bel canto* school than through Garcia" (Coffin, 1989, p.206). Garcia heard his father coached in the role of Almaviva by Rossini during the period when Rossini was hired to compose for, coach, and conduct singers at San Carlo in Naples. Thus, Garcia II was immersed in the technique and style of the Rossini *bel canto* opera while his father performed in Naples. Reid, however, records the decline of *bel canto* in his outline of procedural changes made by Garcia and Lamperti which can be found in Bel Canto: Principles and practices (Reid, 1950, p. 165).

In defining his school of vocal training, Reid delineates the *bel canto* school as being a psychological method as opposed to the application of science to voice

training. He states that "in making a choice between scientific application to voice training and the psychological method of the early teachers of *bel canto*, it is important to remember that one is dealing with a muscular organization" (Reid, 1950, p. 46).

This viewpoint, which states that *bel canto* was purely a psychological method, is incorrect in light of further historical review. Miller quotes the study of acoustic adjustments by Mancini in 1774: "If the harmony of . . . the mouth and 'fauce' is perfect, then the voice will be clear and harmonious. But if these organs act discordantly, the voice will be defective, and consequently the singing spoiled" (Miller, 1991, p. 375). Further scientific interest is seen in a description of respiration in singing by Jean-Baptiste Berard from 1775:

> ". . . the ribs raise outwardly, and . . . the diaphragm . . . descends and compresses the abdomen. . . . For good expiration . . . air must be made to leave with more or less force, with more or less volume, according to the character of the song" (Miller, 1991, p. 375).

Along with Reid, Stanley was another prominent pedagogue in the 1950's; each published a voice book in 1951. While Reid's book defined his school of functional voice training, Stanley's publication was scientific. A review was published in the August, 1951 issue of Musical Courier. The reviewer states that

> the books might have been written, respectively, by a man from Mars and a man from Venus, so radically different are the vocal philosophies behind them . . . Reid seems to know what he is talking about--but so, also, does Stanley. Whom to believe? The proof should lie in the pudding--but here again neither of the two, as far as this writer knows, has produced a pupil that would come anywhere near the claims each sets forth for his teaching principles. And when one gets through reading these two books, each

> excellent in its way one still has no idea why singing today is in the wretched state it is (p. 28)

Reid (1950) further states that Garcia's motivation behind the invention of the laryngoscope was a desire to obtain a short-cut to achieving vocal mastery. This view by Reid must be questioned, however, in light of a review of Part I of Garcia's A complete treatise on the art of singing. Garcia states that no vocalises are found in this work. He discusses in further detail that they were excluded from this method because they no longer have the previous advantage of the complete development of the resources of the voice but, instead, cause problems. A lengthy footnote was added, most of which merits quotation:

> This fact is connected with some curious details of musical history. In the 16th, 17th, and 18th centuries, one would study music only with the aid of the voice. The students specially destined for singing were directed in that study by the same master who had taught them solfege. Sometimes, in order to avoid the difficulties which were then in force, one would replace the names of the notes with a vowel. From this accidentally employed procedure was born the custom, today so common, of teaching indistinctly, by the vocalise, both music reading and the specific song. The present system seems, at the first approach, to be only the continuation of the old system, and yet the application of it is essentially different. Formerly, in the teaching of solfege (la solmisation), the master, by careful precautions, would prevent in advance all the faulty habits which might have been able to prejudice the future studies of the singer. He watched him in the emission of the voice, in the articulation of the names of the notes, in the manner of breathing; he habituated him to a correct and pure feeling for the music, etc. Later, one approached, by means of special and vocalized exercises the complete development of the resources of the voice . . . Today

> the study of music and that of singing are no longer confided to the same master, and the first of these studies is only the incomplete or faulty preparation for the second (Garcia, 1982, edited by D. Paschke, p. xviii).

Contemporary vocal pedagogue, Richard Miller, defines two important objectives for the studio voice teacher. He states that the contemporary voice teacher's studio teaching objectives should be based on the following two points: (a) to analyze vocal problems and (b) to design proper solutions for them. He states that the main goal of the voice teacher should be to do no harm and that:

> every aspect of vocal technique must be in agreement with what is known about healthy vocal function. . . . Above all, as teachers of singing in a scientific age, we must ask ourselves how much we really know about the subject matter we deal with. Do we have facts, or do we rely on anecdotal opinions? Do we know the literature of our own field, as well as that of related fields? (Miller, 1991, p. 380).

Conclusion

There have been many advances in voice science and medicine since Garcia's first view of the vocal folds and the Helmholz resonator. The new generation of technology has made it possible to view the vocal folds and begin to determine the acoustical properties of singing objectively. It is essential for vocal pedagogues to supplement traditional teaching techniques with the instrumentation now available. Since the specifics and technology are continually evolving, vocal pedagogues can facilitate their familiarity with the rapidly changing field through interaction with voice scientists, singing voice specialists, speech-language pathologists, and laryngologists specializing in care of the professional voice.

Today there are numerous workshops and symposia which deal with the scientific aspects of voice function and voice care. Articles are also found in the National Association of Teachers of Singing (NATS) Journal which are scientifically oriented. The Journal of Voice (JOV), which began publication in 1987, is specifically devoted to scientific aspects of the voice, as well as Professional voice: The science and art of clinical care, 2nd Edition by Sataloff (Singular Publications, 1996), and Textbook of performing arts medicine by Sataloff, Brandfonbrener, and Lederman (Raven Press, 1991). Voice surgery by Gould, Sataloff, and Spiegel (Mosby Press), which is a 1993 publication, includes an excellent chart of the function of laryngeal muscles in vocal fold adjustments and a chart detailing the contribution of laryngeal and respiratory muscles to voice control. The most recent texts published in this field are Vocal arts medicine: The care and prevention of professional voice disorders by Benninger, Jacobson, and Johnson (Theime, 1994), and Diagnosis and treatment of voice disorders by Ruben, Sataloff, Korovin, and Gould (Igaku-Shoin, 1995).

CHAPTER III

PROCEDURES FOR THE STUDY

Introduction

The primary purpose of this study was to determine expected function of normal singers among normal training levels for various objective measures and analysis. This chapter contains a discussion of the selection and characteristics of the population, materials selection, procedures for implementation of the study, and the data analysis techniques.

Description of Population

The general population of interest for this study included all undergraduate and graduate students enrolled in private voice lessons during the 1993-1994 academic year at Rice University, Shepherd School of Music. These students were Freshman through Seniors and first and second year Graduate students who were performance majors. To represent the general population of Rice students enrolled in private voice lessons, all undergraduate and graduate students enrolled in private voice lessons were encouraged to participate.

The target sample for this study was 30 students enrolled in applied voice lessons at Rice during the 1993-1994 academic year who had no evidence of vocal pathology. There were 48 students enrolled in applied voice and 31 elected to participate. Three students were eliminated because of noteworthy health or laryngeal abnormality. Therefore, 28 students comprised the subject population of this investigation (consult Appendix A for a breakdown of demographic information).

The following list includes the materials necessary for completion of this study.

Materials

1. Sign-up sheets
2. Subject information sheet (Appendix B)
3. Subject consent form (Appendix C)
3. Questionnaire for each subject (Appendix D)
4. Subject instruction sheet (Appendix E)
5. *American Institute for Voice and Ear Research* protocol for Objective Evaluation Data Collection (Appendix F)
6. DAT Recorder
7. Hohner International harmonica holder
8. Sony EC737 microphone
9. Kay Elemetrics Computer Speech Lab (CSL)
10. HP Deskwriter C Printer
11. Epson Dot Matrix Printer
12. Digital Stopwatch
13. Nose clips
14. Tamarac Presto "Flash" Spirometer
15. Sound treated room
16. Follow-up sign-up sheets

Administration Procedures

This project was submitted for review to the University Committee on Research Involving Human Subjects' (UCRIHS) at Michigan State University and was approved on August 27, 1993, thereby allowing for research preparation to begin (Appendix G). The week before data collection took place, the studio voice teachers were given sign-up sheets and subject information sheets. The subjects signed up for individual times to (a) have a routine ear, nose and throat (ENT)

exam by a licensed otolaryngologist to determine evidence of any vocal pathology and (b) participate in the objective measures administered by the researcher. At the time of data collection, a questionnaire and an instruction sheet were given to each subject. The objective measures consisted of acoustic, phonatory, and respiratory measures. There were three data collection times for each student. The first data collection occurred at the end of the 1993 Fall semester (October), the second data collection, at the beginning of the 1994 Spring semester (January), and the third was at the end of the 1994 Spring semester (April) prior to voice juries. Each subject was asked to complete the same objective measures for all three data collections as administered by the researcher. These measures consisted of acoustic, phonatory, and respiratory measures. They occurred at identical points in time for all participants in this study.

Acoustic Measures

The acoustic measures consisted of collecting (a) the fundamental frequency (Fo) of a conversational sample and (b) a series of measures from the spoken and sung sounds of the vowels /ɑ/, /i/, and /u/. These measures included the following indicators: Jita, JITT, RAP, PPQ, sPPQ, vFo, Shimmer in dB, SHIM, APQ, sAPQ, vAm, NHR, VTI, SPI, FTRI, ATRI, Fftr, and Fatr.

Phonatory Measures

The phonatory measures consisted of collecting the physiological frequency range of phonation (FRP), Musical Frequency Range of Phonation (MFR), maximum phonation time (MPT) of /s/ and /z/ along with the s/z ratio, and the maximum phonation time of the vowels /ɑ/, /i/, /u/, using both spoken and sung production.

Respiratory Measures

The respiratory measures consisted of collecting the mean flow rate (MFR) and pulmonary function testing (PFT's). The PFT primary measures of concern were the FVC, FEV 1.0, and FEF 25-75%.

Objective Measures Protocol

The acoustic measures were recorded on a SONY DAT for later analysis by the Computer Speech Lab (CSL). Before the actual data collection began, each subject participated in two practice items using spoken and sung productions on the vowel /ɑ/ of the protocol. The subjects were then asked to state their name, the date, their age and to read the Marvin Williams Passage in order to record their conversational speaking range. Following this process, phonation ranges were recorded on the SONY DAT for later analysis by the CSL. Subjects were requested to produce a vocal slide on the vowel /ɑ/ beginning in mid-range and sliding up and then beginning in mid-range and sliding down to record their physiological frequency range of phonation (FRP). Next the subjects were asked to sing a step-wise scale on the vowel /ɑ/ beginning in mid-range and singing up and then beginning in mid-range and singing down to record the musical frequency range of phonation. The subjects were asked to hold or maintain the upper and lower limits for one to two seconds.

The subjects were then asked to produce a spoken sound on the vowels /ɑ/, /i/, and /u/ at a comfortable pitch and loudness level. Five trials lasting 5 seconds for each vowel were recorded. Next the subjects were asked to produce a sung sound on the vowels /ɑ/, /i/, and /u/ at a comfortable pitch and loudness level (the chosen pitch was determined by using a keyboard for repetition in data collections two and three). Five trials lasting 5 seconds for each vowel were recorded.

The subjects completed the maximum phonation times next. For MPT the subjects were asked to take a big breath and produce spoken and sung sounds on the vowels /ɑ/, /i/, and /u/ for as long as possible. The subjects were next asked to take a big breath and produce /s/ and then /z/ for as long as possible. One trial was recorded for each of these measures. However, the subject was able to attempt another trial if he/she did not feel that the first trial was adequate. A hand-held digital stopwatch, accurate to 1/100 of a second, was used to record the duration of the Phonation Times.

Following the acoustic and phonatory measures, the subjects completed respiratory measures. The first respiratory measure was the PFT's. Each subject was given a demonstration with the following instructions: "You will take as big a breath as you possibly can, put your mouth around the tube making sure that no air escapes from the corners of your mouth, and blow the air through the tube in one big, sharp blast. I will cheer you on while you keep trying to blow. When I tell you, you will breathe in as sharply and as hard as you can. You will keep your mouth on the tube the entire time and not take it off until I tell you. In order to ensure that no air escapes from your nose you will need to wear noseclips. I will give you all of your instructions. Please do not do anything until I tell you." Three PFT trials were recorded. The spirometer was calibrated prior to each occasion.

The subject was asked to take a fairly big breath and produce a spoken /ɑ/ vowel with nose clips on while comfortably blowing into the spirometer for only as long as was comfortably possible to record the MFR. A hand-held digital stopwatch, accurate to 1/100 of a second, was used to record the duration of the flow.

After completion of the objective measures, subjects filled out a questionnaire which included demographic data such as age, sex, years in school,

years of voice study, number of different voice teachers and the following questions: (a) did you have private voice lessons before your first year of college study and if yes, how long? (b) do you play a brass or woodwind instrument and if yes, what do you play and for how long have you played it? (c) are you a cheerleader? (d) are you an aerobics instructor? (e) are you currently participating in ensemble singing? (f) are you currently directing an ensemble? (g) are you actively involved in athletics? (h) do you perform with a live band? (i) do you have a job? (j) do you eat late at night, near bedtime? and (k) how much do you talk on the telephone a day? The subjects were asked to comment on their physical health at the time of data collection.

Hypothesis

The following hypothesis was examined during this study: Normal voice functions for trained singers differ from published normative data for objective voice analysis.

Data Analysis Procedure

This study involved collecting several objective measures in the acoustic, phonatory, and respiratory domains on each of three occasions. On each occasion, five repetitions or trials were employed to develop stable measures in the acoustic domain. On each of the three occasions, for each of 19 measures in the acoustic domain, Cronbach's coefficient alpha (1951) was estimated over the five measurement trials. The result of these reliability calculations are displayed over the three occasions in Tables 1 to 6 for spoken and sung productions for the vowels /ɑ/, /i/, and /u/.

Table 1

Reliability Calculations for Spoken /ɑ/

	Occasion		
Measure	1	2	3
Fo	.9998	.9998	.9997
Fftr	.2355	.0896	.3486
Fatr	.6545	.3245	.2850
Jita	.8674	.9427	.9355
Jitt	.8610	.9427	.9355
RAP	.8607	.9179	.9394
PPQ	.8697	.9212	.9473
sPPQ	.8356	.8723	.9225
vFo	.8610	.9317	.9317
ShdB	.9456	.9825	.9854
Shim	.9476	.9820	.9853
APQ	.9652	.9853	.9859
sAPQ	.9147	.9626	.9402
vAm	.7949	.8546	.7541
NHR	.8934	.9587	.9779
VTI	.7299	.9315	.9119
SPI	.9652	.9605	.9640
FTRI	.8899	.8474	.8116
ATRI	.6949	.7441	.5753
Median	.867	.939	.939

Median across all 3 Occasions = .921

Because the median reliability of the 19 acoustic measures was stable across the three occasions, the five trials were combined to produce a precise indicator of each acoustic measure.

Table 2

Reliability Calculations for Spoken /i/

Measure	Occasion 1	2	3
Fo	.9999	.9944	.9999
Fftr	.3895	.4698	.7984
Fatr	.2608	.2062	.4046
Jita	.8759	.8405	.8963
Jitt	.9227	.8979	.8976
RAP	.9242	.8995	.9004
PPQ	.9241	.9004	.8980
sPPQ	.9194	.8827	.8836
vFo	.8730	.8438	.8759
ShdB	.9156	.9610	.9561
Shim	.9126	.9616	.9561
APQ	.9299	.9610	.9652
sAPQ	.9708	.9193	.9389
vAm	.9426	.8641	.8891
NHR	.9063	.8992	.8722
VTI	.9022	.9624	.9035
SPI	.9882	.9719	.9701
FTRI	.8539	.7729	.8438
ATRI	.9109	.6328	.8766
Median	.916	.899	.898

Median across all 3 Occasions = .900

Because the median reliability of the 19 acoustic measures was stable across the three occasions, the five trials were combined to produce a precise indicator of each acoustic measure.

Table 3

Reliability Calculations for Spoken /u/

	Occasion		
Measure	1	2	3
Fo	.9999	.9996	.9999
Fftr	.0358	.8688	.5291
Fatr	.2445	.1020	.5312
Jita	.7876	.8795	.8225
Jitt	.9072	.8932	.8576
RAP	.9088	.8970	.8632
PPQ	.9117	.8965	.8613
sPPQ	.8782	.8941	.8099
vFo	.8740	.8624	.7983
ShdB	.9358	.9480	.9397
Shim	.9292	.9492	.9370
APQ	.9421	.9666	.9560
sAPQ	.9756	.9305	.9754
vAm	.9292	.8479	.9428
NHR	.9410	.8542	.7461
VTI	.7231	.7954	.7574
SPI	.9696	.9782	.9801
FTRI	.9310	.8379	.7742
ATRI	.9224	.8207	.8232
Median	.922	.893	.858

Median across all 3 Occasions = .894

Because the median reliability of the 19 acoustic measures was stable across the three occasions, the five trials were combined to produce a precise indicator of each acoustic measure.

Table 4

Reliability Calculations for Sung /ɑ/

	Occasion		
Measure	1	2	3
Fo	1.0	1.0	1.0
Fftr	.9658	.9232	.9178
Fatr	.9016	.8618	.7260
Jita	.9789	.9155	.9572
Jitt	.9647	.9309	.9167
RAP	.9618	.9361	.9192
PPQ	.9646	.9373	.9211
sPPQ	.9917	.9910	.9927
vFo	.9798	.9812	.9762
ShdB	.9729	.9720	.9807
Shim	.9757	.9715	.9799
APQ	.9703	.9849	.9851
sAPQ	.9478	.9568	.9713
vAm	.9602	.8378	.9041
NHR	.9935	.9956	.9979
VTI	.9644	.9676	.9527
SPI	.9844	.9840	.9674
FTRI	.9921	.9909	.9896
ATRI	.9026	.8417	.8758
Median	.970	.968	.967

Median across all 3 Occasions = .968

Because the median reliability of the 19 acoustic measures was stable across the three occasions, the five trials were combined to produce a precise indicator of each acoustic measure.

Table 5

Reliability Calculations for Sung /i/

	Occasion		
Measure	1	2	3
Fo	1.0	1.0	1.0
Fftr	.8978	.9770	.9437
Fatr	.9429	.8415	.9092
Jita	.9772	.9821	.9398
Jitt	.9594	.9583	.9226
RAP	.9580	.9567	.9251
PPQ	.9558	.9603	.9271
sPPQ	.9845	.9931	.9899
vFo	.9682	.9841	.9783
ShdB	.9735	.9749	.9898
Shim	.9768	.9755	.9895
APQ	.9817	.9866	.9896
sAPQ	.9712	.9667	.9849
vAm	.9792	.9253	.9425
NHR	.9878	.9959	.9930
VTI	.9446	.9736	.9747
SPI	.9852	.9473	.9805
FTRI	.9843	.9924	.9894
ATRI	.9631	.9217	.9281
Median	.974	.975	.978

Median across all 3 Occasions = .975

Because the median reliability of the 19 acoustic measures was stable across the three occasions, the five trials were combined to produce a precise indicator of each acoustic measure.

Table 6

Reliability Calculations for Sung /u/

	Occasion		
Measure	1	2	3
Fo	1.0	1.0	1.0
Fftr	.9521	.9046	.9792
Fatr	.9550	.9051	.9207
Jita	.9835	.9105	.9617
Jitt	.9652	.9144	.9228
RAP	.9641	.9203	.9272
PPQ	.9670	.9254	.9223
sPPQ	.9896	.9913	.9907
vFo	.9832	.9852	.9772
ShdB	.9780	.9577	.9785
Shim	.9797	.9595	.9812
APQ	.9809	.9843	.9806
sAPQ	.9767	.9741	.9770
vAm	.9793	.9123	.9492
NHR	.9829	.9932	.9932
VTI	.8543	.9353	.9312
SPI	.9856	.9857	.9901
FTRI	.9885	.9913	.9877
ATRI	.9609	.9372	.9405
Median	.979	.958	.977

Median across all 3 Occasions = .977

Because the median reliability of the 19 acoustic measures was stable across the three occasions, the five trials were combined to produce a precise indicator of each acoustic measure.

Data from the three occasions for each measure in the acoustic domain were subjected to a one-way, repeated-measures analysis of variance to determine whether any patterns of change were present over the eight-month training program. When the ANOVA detected non-equivalent means over the three occasions, simultaneous post hoc trend procedures were employed to determine the particular nature of the trend. Since 19 interrelated acoustic measures were involved, a system of simultaneous 99% confidence intervals was established for testing the individual acoustic measures, following the Dunn-Bonferroni strategy.

Subsequently, the same repeated-measures analysis of variance and simultaneous post hoc trend procedures were applied to the twenty measures in the phonatory (16) and respiratory (4) domains. Since 20 interrelated phonatory and respiratory measures were involved, a system of simultaneous 99% confidence intervals was established for testing the individual measures again following the Dunn-Bonferroni strategy.

All of the above analyses were executed using the *Statistical Package for the Social Sciences (SPSS)* for windows (version 6.1). These analyses were carried out on a Compaq Prolinea 486 with 16 megabyte memory and 1 gigabyte ram hard disk.

A number of variables were not controlled in this study: (a) reflux, (b) studio teaching technique, (c) practice dedication, (d) regularity of lessons, (e) voice use (job, school/church ensembles, telephone), (f) speaking voice technique, (g) vocal health habits (sleep, eating, etc.), and (h) the time of the objective measure recording and its effect on the measures.

CHAPTER IV

ANALYSIS OF DATA

There are four assumptions for univariate repeated measures analysis: (1) independence of observations, (2) multivariate normality, (3) homogeneity of variance-covariance matrices for males and females, and (4) sphericity (i.e., variance of the differences for all pairs of repeated measures are equivalent). The first three assumptions are also required for the multivariate approach, but the sphericity assumption is not necessary. In the multivariate approach the three repeated (occasion) measures are transformed into two new variables, "linear" trend and "quadratic" trend, which are uncorrelated. This means that the pattern of covariance among the three repeated measures is transformed into two independent components for conceptual ease in simplifying explanations.

In the univariate repeated measures approach, when the sphericity assumption is not met, the calculated F-ratio has a larger risk of committing a Type I error than the investigator has established. The *actual* level of significance is far larger (and not known) than the *nominal* level of alpha set by the investigator. In other words, one sets alpha level at .05 but may actually be rejecting falsely 8% or 10% of the time. The extent to which the covariance matrix deviates from sphericity is reflected in the parameter called Epsilon (ε) (Greenhouse and Geisser, 1959). If sphericity is met, then $\varepsilon=1$, with the worst possible violation being the value of $\varepsilon = 1/(3-1) = 1/2$. To adjust for using the positive bias, Greenhouse and Geisser suggested altering the degrees of freedom from k-1 and (k-1) (n-1) to 1 and n-1 respectively.

Doing this makes the test very conservative, since the adjustment is for the worst possible case. A more reasonable approach is to estimate ε, then adjust the degrees of freedom from k-1 and (k-1) (n-1) to ε(k-1) and ε(k-1) (n-1).

Numerous statistical studies have concluded that this procedure keeps the *actual* alpha close to the *nominal* alpha.

In terms of controlling for type-I error, there is no real basis for preferring the multivariate approach, since the modified univariate test (multiplying the degrees of freedom by ε) yields an "honest" error rate. The choice then involves a question of power. Now assuming sphericity is met, the univariate test is more powerful. When sphericity is violated, however, the situation is much more complex. "When small but reliable effects are present with the effects being highly variable . . . the multivariate test is far more powerful than the univariate test" (Davidson, 1972, p. 452). O'Brien and Kaiser (1985) examined several studies and concluded no procedure is uniformly more powerful or even usually the most powerful. Other things being equal, as the sample size n decreases, the multivariate test is relatively less powerful than the univariate mixed-model test. In this exploratory study, both univariate and multivariate tests have been routinely applied, because they may differ in the effects they may discern. By setting the significance level of each test at .025, we can control the overall level of significance to be .05.

Spoken Phonation of the /ɑ/ vowel

Fundamental Frequency Measures

F_o (Fundamental Frequency)

To examine the measure F_O of the spoken /ɑ/ vowel, it was first necessary to determine if the following assumptions could be met: homogeneity of variance-covariance matrices (3 above) i.e., there is a similarity of patterns between males and females, and sphericity (4 above) (i.e., is there congruity from element to element). The former assumption was met; however, the latter was not . Therefore, the multivariate approach was used to examine F_O. Analysis

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determined that main effects for both gender and occasion, and the interaction effect of gender with occasion, were all present for the dependent variable F_0.

There was a significant difference between males and females when the variable F_0 was pooled over the three occasions; males scored lower than females with a power of 1.0 ($F1,26 = 102.63$, $p < .001$). The value of eta squared indicated that 80% of the variability of pooled F_0 was aligned with gender. Wilks' Lambda ($\Lambda = 0.59$) indicated that there was a significant difference over the three testing occasions when the variable F_0 was pooled over gender ($P < .001$). The value of eta squared indicated that 41% of the variability in F_0 of spoken /ɑ/, pooled over genders, was aligned with testing occasion (the repeated measures). The power with which the trend was detected was .96, nearly equivalent to that of the gender effect. However, the effect of gender was stronger than that of the training over time by a ratio of 2:1. From the transformed variables, a significant positive quadratic component over the three testing occasions was found. The positive quadratic component indicated that F_0 decreased over time, bottomed out, and increased from occasion two to occasion three. This component of trend reflects a dramatic training effect over time, regardless of gender.

Finally, Wilks' Lambda for the interaction effect ($\Lambda = 0.76$, $F_{2,25} = 3.93$) indicated that males differed from females by differing amounts over occasions ($p < .05$). The value of eta squared revealed that 24% of the variability in F_0 was aligned with the interaction of gender and test occasion. However, the power of this test was only 0.65.

The univariate approach also indicated similar significant differences and quadratic trend over testing occasion. The conservative adjustment to degrees of freedom given assumption violation cited above indicated that there is no interaction between gender and testing occasion (Appendix H.1).

Jita (Absolute Jitter in us)

To examine of the measure Jita of the spoken /ɑ/ vowel, it was first necessary to determine if the homogeneity of variance-covariance matrices between males and females and the sphericity assumptions could be met. Although the homogeneity of variance assumption was satisfied on occasions two and three, the limited group sizes (13 males and 15 females) suggested the variances were marginally different on occasion one. Accordingly, only the multivariate approach was used to examine Jita.

Pooling over the three occasions, no difference between males and females was present for the dependent variable Jita. ($F_{1,26} = 2.01$, $p > .05$). There was no difference over occasions ($\Lambda = 0.98$, $F_{2,25} <$, $p > .50$). There was also no interaction effect between gender and occasion ($\Lambda = 0.81$, $F_{2,25} = 2.88$, $p < .08$). The univariate approach also reported that there is no significant interaction between gender and occasion. However, this approach indicated that there is a significant difference over occasions (df = 1.58, 41.16 = 4.27, $p < .03$). The value of eta squared revealed that 14% of the variability is aligned with testing occasion; however, the power is .72. Subsequent testing of trend indicated that the nature of this trend is a decreasing linear pattern over the testing occasion (the repeated measures) (Appendix H.2).

Jitt (Jitter Percent)

Examination of the measure Jitt of the spoken /ɑ/ vowel indicated that the assumption of homogeneity of variance-covariance matrices between males and females was met, whereas the assumption of sphericity was not met (or is marginal at best). Therefore, the multivariate approach was used to examine Jitt. Analysis determined that both main effects of gender and occasion were present.

There was a significant difference between males and females (males scoring lower than females) on the variable Jitt ($p < .05$). The value of eta squared indicated that 18% of the variability was aligned with gender. Wilks' Lambda indicated that there was a significant difference over the occasions (Λ = 0.67, $F_{2,25} = 6.13$, $p < .01$). The value of eta squared for occasions revealed that 33% of the variability in Jitt of spoken /ɑ/ was aligned with the testing occasion (the repeated measures). Comparison of the two n^2 for gender and occasion reveals that occasion is twice the strength of gender. When the individual components are tested separately, both are significant comparing two components to the trend over the three testing occasions. The linear component yields an $F_{1,26} = 10.49$, $p < .005$, whereas the quadratic component yields an $F_{1,26} = 7.88$, $p < .01$. The two n^2 are fairly comparable, 0.29 and 0.23 respectively.

The results of the univariate approach support the results of the multivariate approach but with more power. This change in power is due to the increase in estimates required by the multivariate approach with a small sample size of 28 subjects.

Finally, these was no interaction between gender and occasion detected with either the multivariate ($\Lambda = .95$, $F_{2,25} < 1$, $p > .50$) or univariate approach (F 1.64, 42.54 < 1, $p > .40$)(Appendix H.3).

RAP (Relative Average Perturbation)

Examination of the measure RAP of the spoken /ɑ/ vowel indicated that both assumptions of homogeneity of variance-covariance matrices between males and females, and sphericity were met. Therefore, the univariate approach was used to examine RAP. Analysis determined that both main effects, that of gender and occasion, were present for the dependent variable RAP.

There was a significant difference between males and females (males scored significantly lower than females) of the variable RAP ($F_{1,26} = 6.50$, $p < .02$). Pooled over occasion, the value of eta squared indicated that 20% of the variability of RAP was aligned with gender. The power of the test was .69. There was also a significant difference over testing occasion ($F_{2,52} = 9.42$, $p < .001$). The value of eta squared indicated that 27% of the variability of RAP was aligned with testing occasion when pooled over genders. The effect of testing occasion was only 7% stronger that the effect of gender. However, the power of the test for occasion effect was .97 compared to .69 of the gender effect. This indicates that the testing occasions effect is nearly as strong as it can be with the existing small group sizes. However, the power of the test indicates that the gender effect may be enhanced if group sizes were increased.

There was no interaction between gender and testing occasion. From the transformed variables no significant trend over the three testing occasions is found ($F_{2,52} < 1$, $p > .40$). This reflects that essentially no training effect was detected over time (Appendix H.4).

PPQ (Pitch Perturbation Quotient)

For the measure PPQ of the spoken /ɑ/ vowel over the three occasions, the assumption of homogeneity of variance-covariance matrices between males and females was met. However, the sphericity assumption was not met. Therefore, the multivariate approach was used to examine PPQ. Analysis determined that both main effects for gender and occasion were present.

Pooling over occasions, there was a significant difference between males and females (males scoring significantly lower than females) of the variable PPQ ($F_{1,26} = 5.46$, $p < .03$). The value of eta squared indicated that 17% of the variability was aligned with gender; the power of this test was near a chance level

of 0.61. The most dramatic effect tested was that of occasion. Wilks' Lambda (Λ = 0.67, $F_{2,25}$ = 6.21, p< .01) indicated that there was a significant difference over the occasions. Although 17% of the variability in PPQ of spoken /a/ pooled over gender was aligned with gender, 33% of the variability (n^2) was aligned with the testing occasion pooled over genders (the repeated measures). The ratio of almost 2:1 in strength of variability indicates that the stronger effect resides with test occasion. The power of the multivariate test was 0.85, whereas the power of the univariate test was 0.98 (F 1.51, 39.14 = 10.03; p < .001). Over the three testing occasions, both the linear trend ($F_{1,26}$ = 10.35, p < .01) and quadratic trend ($F_{1,26}$ = 9.50, p < .01) are significant. This reflects a dramatic training effect over time.

There was no interaction effect between gender and testing occasion using either the multivariate or the univariate approach.

The results of the univariate approach support the results of the multivariate approach but with more power. This change in power is due to the increase in estimates required by the multivariate approach with a small sample size of 28 subjects (Appendix H.5).

sPPQ (Smoothed Pitch Perturbation Quotient)

Examination of the measure sPPQ of the spoken /ɑ/ vowel indicated that the assumptions of homogeneity of variance-covariance matrices between males and females and sphericity were met. Therefore, the univariate approach was used to examine PPQ. Analysis determined that the main effect of occasion was present for the dependent variable sPPQ.

There was no difference between males and females on the variable PPQ ($F_{1,26}$ < 1, p > .50). There was a significant difference over testing occasions ($F_{2,52}$ = 9.38, p < .001). The value of eta squared indicated that 27% of the

variability (power rating = .97) in sPPQ of spoken /ɑ/ pooled over genders was aligned with testing occasion (the repeated measures). Examination of the independent components of trend indicated the presence of a significant linear trend ($F_{1,26} = 9.62$, $p < .01$) and quadratic component trend ($F_{1,26} = 9.04$, $p < .01$). Eta sums for linear trend are respectively 0.30 and 0.21 indicating the former is 1 1/2 times the strength of the latter. This reflects a dramatic training effect over time. Finally, there was no interaction between gender and testing occasion (Appendix H.6).

vFo (Fundamental Frequency Variation)

Examination of the measure vFo of the spoken /ɑ/ vowel indicated that the assumption of homogeneity of variance-covariance matrices over the three occasions between males and females was met. However, the sphericity assumption was not met. Therefore, the multivariate approach was used to examine vFo. Analysis determined that the main effect of occasion was present for the dependent variable vFo.

There was no difference between males and females of the variable vFo ($F_{1,26} < 1$, $p > .70$). The most dramatic effect tested was that of occasion. Wilks' Lambda ($\Lambda = 0.72$, $F_{2,25} = 4.85$, $p < .02$) indicated that there was a significant difference over the occasions. The value of eta squared for occasion revealed that 28% of the variability pooled over genders (power rating = .75) was aligned with the testing occasion (the repeated measures). From the two independent trend variables considered separately, there was a significant linear trend over the three testing occasions ($F_{1,26} = 6.3$, $p < .02$) and a significant quadratic trend ($F_{1,26} = (.45$ $p < .01$). The n^2 associated with the two trends were 20% and 27% respectively. This reflects a dramatic training effect over time. Finally, there was no interaction between gender and testing occasion.

The results of the univariate approach support the results of the multivariate approach but with more power (0.93). This change in power is due to the increase in estimates required by the multivariate approach with a small sample size of 28 subjects (Appendix H.7).

Amplitude Measures

ShdB (Shimmer in decibels)

Examination of the measure ShdB of the spoken /ɑ/ vowel indicated that the assumption of homogeneity of variance-covariance matrices between males and females of the three occasions was met. However, the sphericity assumption, or constant correlation over occasions, was not met. Therefore, the multivariate approach was used to examine ShdB. Analysis determined that no main or interaction effects were present for the dependent variable ShdB.

There was no difference between males and females of the variable ShdB ($F < 1$, $p > .95$). There was no difference over testing occasion (the repeated measures) ($\Lambda = 0.95$, $F_{2,25} < 1$, $p > .50$). Finally, there was no interaction between gender and occasion ($\Lambda = 0.95$, $F_{2,25} < 1$, $p > .50$). These results reflect that there is no training effect over time. The results of the univariate approach support the results of the multivariate approach (Appendix I.1).

Shim (Shimmer Percent)

Examination of the measure Shim of the spoken /ɑ/ vowel indicated that the assumption of homogeneity between males and females of variance-covariance matrices for the three occasions was met. However, the assumption of sphericity was not met. Therefore, the multivariate approach was used to examine Shim. Analysis determined that no main effects were present for the dependent variable Shim.

There was no difference between males and females of the variable Shim ($F_{1,26} < 1$, $p > .95$). There was no difference over testing occasion (the repeated measures) ($\Lambda = 0.96$, $F_{2,25} < 1$, $p > .60$), and there was no interaction effect of gender over occasion ($\Lambda = 0.93$, $F_{2,25} < 1$, $p > 0.40$). These results reflect that there is no training effect over time. The results of the univariate approach support the results of the multivariate approach (Appendix I.2).

APQ (Amplitude Perturbation Quotient)

Examination of the measure APQ of the spoken /ɑ/ vowel indicated that the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions was met. The assumption of sphericity was not met. Therefore, the multivariate approach was used to examine APQ. Analysis determined that the main effect of occasion was present for the dependent variable APQ.

There was no difference between males and females of the variable APQ ($F_{1,26} = 2.01$, $p > .15$). Wilks' Lambda ($\Lambda = 0.77$) indicated that there was a significant difference over the occasions ($F_{2,25}$, $p < .05$). The value of eta squared for occasion revealed that 23% of the variability in APQ of spoken /ɑ/ was aligned with the testing occasion (the repeated measures). A significant linear trend ($F_{1,26} = 4.85$, $p < .04$) and quadratic trend ($F_{1,26} = 7.25$, $p < .02$) over the three testing occasions was found. The power of both of these tests was in excess of 0.99, revealing a dramatic training effect over time. Finally, there was no interaction between gender over occasion ($\Lambda = 0.86$, $F_{2,26} = 2.05$, $p > .15$) (Appendix I.3).

sAPQ (Smoothed Amplitude Perturbation Quotient)

Examination of the measure sAPQ of the spoken /ɑ/ vowel indicated that the assumption of homogeneity between males and females of variance-covariance matrices over the three testing occasions was met. However, the sphericity assumption was not met. Therefore, the multivariate approach was used to examine sAPQ. Analysis determined that the main effect of occasion was present for the dependent variable sAPQ.

There was no difference between males and females of the variable sAPQ ($F_{1,26} < 1$, $p > .60$). Wilks' Lambda ($\Lambda = 0.47$) indicated that there was a significant difference over the occasions ($F_{2,25} = 14.01$, $p < .001$). The value of eta squared for occasion revealed that 53% of the variability in sAPQ of spoken /ɑ/ was aligned with the testing occasion (the repeated measures). A significant downward linear trend ($F_{1,26} = 23.15$, $p < .001$)over the three testing occasions, and a significant positive quadratic component ($F_{1,26} = 25.77$, $p < .001$) over the three testing occasions was found. The test of the two independent trend variables were nearly equivalent in power (both 0.98). Additionally, the two components are nearly equivalent in strength (47% and 49%). The downward linear trend indicates that sAPQ decreased over time. The positive quadratic component indicates that although sAPQ decreased over time, it bottomed out and slightly increased from occasion two to occasion three. These two components of trend reflect a dramatic training effect over time. Finally, there was no interaction between gender over occasion ($\Lambda = 0.96$, $F_{2,26} < 1$, $p > .60$) (Appendix I.4).

vAm (Peak-Amplitude Variation)

Examination of the measure vAm of the spoken /ɑ/ vowel indicated that the assumption of homogeneity between males and females of variance-

covariance matrices over the three occasions was met. However, the sphericity assumption was not met. Therefore, the multivariate approach was used to examine vAm. Analysis determined that the main effect of occasion was present for the dependent variable vAm.

There was no difference between males and females of the variable vAm ($F_{1,26} = 1.46$, $p > .20$). Wilks' Lambda ($\Lambda = 0.55$) indicated that there was a significant difference over the occasions ($F_{2,25} = 10.29$, $p < .01$). The value of eta squared for occasion revealed that 45% of the variability in vAm of spoken /ɑ/, pooled over genders, was aligned with the testing occasion (the repeated measures). The power of the test was 0.98. A significant downward trend over the three testing occasions was found ($F_{1,26} = 21.36$, $p < .001$). The downward linear trend indicates that sAPQ decreased over time. This component of trend reflects a dramatic training effect over time. Finally, there was no interaction between gender over occasion. The results of the univariate approach support the results of the multivariate approach (Appendix I.5).

Noise Related Measures

NHR (Noise to Harmonic Ratio)

Examination of the measure NHR of the spoken /ɑ/ vowel indicated that both assumptions of homogeneity between males and females of variance-covariance matrices over the three occasions, and sphericity were met. Therefore the univariate approach was used to examine NHR. Analysis determined that the main effect of gender was present for the dependent variable NHR.

There was a significant difference between males and females of the variable NHR ($F_{1,26} = 6.48$, $p < .02$). The value of eta squared indicated that 20% of the variability in NHR of spoken /ɑ/, pooled over occasion, was aligned with gender. The power of this test was 0.68. There was no difference over the

occasions ($F_{2,52} < 1$, $p > .40$). Although 20% of the variability is aligned with gender, the power of the indicated test was only 2/3 marginally greater than chance. Finally, There was no interaction between gender over occasion ($F_{2,52} = 1.24$, $p > .30$) (Appendix J-1).

VTI (Voice Turbulence Index)

Examination of the measure VTI of the spoken /ɑ/ vowel indicated that both assumptions of homogeneity between males and females of variance-covariance matrices over the three occasions, and sphericity were met. Therefore, the univariate approach was used to examine VTI. Analysis determined that the main effect of occasion was present for the dependent variable VTI.

There was no difference between males and females of the variable VTI ($F_{1,26} = 2.45$, $p > .10$). There was significant difference over occasion (the repeated measures) ($F_{2,52} = 9.20$, $p < .001$). The value of eta squared indicated that 26% of the variability in VTI of spoken /ɑ/, pooled over gender, was aligned with testing occasion. The power of the test was 0.97. There was no interaction between gender over occasion ($F_{2,52} < 1$, $p > .90$). A significant upward linear trend ($F_{1,26} = 7.18$, $p < .02$) and a significant quadratic trend ($F_{1,26} = 10.93$, $p < .01$) open downward were detected. The trends are of nearly equivalent strength (Appendix J-2).

SPI (Soft Phonation Index)

Examination of the measure SPI of the spoken /ɑ/ vowel indicated that neither the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions, nor sphericity was met. Therefore, the multivariate approach was used to examine SPI. Analysis determined that the main effect of occasion was present for the dependent variable SPI.

There was no difference between males and females of the variable SPI ($F_{1,26} < 1$, $p > .60$). Wilks' Lambda ($\Lambda = 0.43$, $F_{2,25} = 16.73$, $p < .001$) indicated that there was significant difference over occasion (the repeated measures). The value of eta squared revealed that 57% of the variability in SPI of spoken /ɑ/, pooled over gender, was aligned with testing occasion. The power of the test was 1.0. There was no interaction between gender over occasion ($\Lambda = 0.92$, $F_{2,25} = 0.94$, $p > .40$). A significant downward linear trend ($F_{1,26} = 30.66$, $p < .001$) over the three testing occasions and a significant positive quadratic trend ($F_{1,26} = 18.10$, $p < .001$) over the three testing occasions were found. The downward linear trend was stronger than the positive quadratic component (54% vs. 41%); the power of the two tests were equivalent (0.99). The downward linear trend indicates that SPI decreased over time. The positive quadratic component indicates that although SPI decreased over time, it bottomed out and slightly increased from occasion two to occasion three. These two components of trend reflect a dramatic training effect over time (Appendix J.3).

Tremor Related Measures

Ftri (F_0 Tremor Intensity Index)

Examination of the measure Ftri of the spoken /ɑ/ vowel indicated that the assumption of homogeneity of variance-covariance matrices between males and females was met. The test of sphericity was also met. Therefore, the univariate approach was used to examine Ftri.

There was a significant difference between males and females of the variable Ftri ($F_{1,26} = 5.02$, $p < .05$). Males scored significantly higher than females. The value of eta squared indicated that 16% of the variability of Ftri, pooled over occasions, was aligned with gender. However, the power of the test was 0.58, which reveals that it is due to not much more than chance that 16% of

the variability is aligned with gender. There was no difference over testing occasion ($F_{2,52} = 5.00$, $p > .35$). There was no interaction between gender and testing occasion ($F_{2,52} = 2.39$, $p > .10$). Therefore, there was no dramatic training effect over time (Appendix K.1).

ATRI (Amplitude Tremor Intensity Index)

Examination of the measure ATRI of the spoken /ɑ/ vowel indicated that both the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions, and the assumption of sphericity was met. Therefore, the univariate approach was used to examine ATRI. Analysis determined that the main effect of occasion was present for the dependent variable ATRI.

There was no difference between males and females of the variable vAm ($F_{1,26} < 1$ $p > .30$). There was a significant difference over the occasions ($F_{2,52} = 11.04$, $p < .001$). The value of eta squared for occasion revealed that 30% of the variability (power rating = .98) in ATRI of spoken /ɑ/, pooled over genders, was aligned with the testing occasion (the repeated measures). A significant downward trend ($F_{1,26} = 16.69$, $p < .001$) over the three testing occasions was found. Additionally, a significant quadratic trend ($F_{1,26} = 6.36$, $p < .02$) was detected. The ratio of strengths of these two trends was 2:1, reflected by the eta squares of 34% and 19% respectively. The downward linear trend indicates that ATRI decreased over time. These component of trend reflects a dramatic training effect over time. Finally, there was no interaction between gender over occasion ($F_{2,52} < 1$, $p > .80$) (Appendix K.2).

Fftr (F_o Tremor Frequency)

Examination of the measure Fftr of the spoken /ɑ/ vowel indicated that the assumption of homogeneity of variance-covariance matrices between males and females was tenuous. However, the sphericity assumption was clearly met. Therefore, both the multivariate and univariate approaches were used to examine Fftr. Analysis determined that no main effect was present for the dependent variable Fftr.

There was neither a difference between males and females of the variable Ftri ($F_{1,26} < 1$, $p > .80$) nor a difference over testing occasion ($F_{2,52} < 1$, $p > .80$) (the repeated measures). Finally, no interaction between gender and testing occasion was detected ($F_{2,52} < 1$, $p > .80$). Therefore, there was no training effect over time (Appendix K.3).

Fatr (Amplitude Tremor Frequency)

Examination of the measure Fatr of the spoken /ɑ/ vowel indicated that both assumptions of homogeneity between males and females of variance-covariance matrices over the three occasions and sphericity were met. Therefore, the univariate approach was used to examine Fatr. Analysis determined that no main effect was present for the dependent variable Fatr.

There was no difference between males and females of the variable Fatr ($F_{1,26} < 1$, $p > .80$). There was no difference over the occasions ($F_{2,52} < 1$, $p > .60$). Finally, There was no interaction between gender over occasion ($F_{2,52} = 1.39$, $p > .30$). These results indicate no differences by gender or over occasion through out the training (Appendix K.4).

Sung Phonation of the /ɑ/vowel

Fundamental Frequency Measures

F_o (Fundamental Frequency)

To Examine the measure F_O of the sung /ɑ/ vowel, it was first necessary to determine if the following assumptions could be met: Homogeneity of variance-covariance matrices over the three occasions between males and females was met; the near perfect correlation of the three occasions placed emphasis on the variances, which despite being three -digit numbers, diminished over the three occasions. The sphericity assumption was met . Therefore, both the multivariate and univariate approaches was used and compared to examine F_O. Analysis determined that the main effect of gender was present for the dependent variable F_O.

There was a significant difference between males and females of the variable F_O ($F_{1,26} = 53.65$, $p < .001$). The value of eta squared indicated that 67% of the variability in F_O pooled over occasion was aligned with gender. There was also no statistical difference detected over the testing occasion (repeated measures). This was the case for both the multivariate ($\Lambda = 0.89$, $F_{2,25} = 1.51$, $p > .20$)and univariate ($F_{2,52} = 1.07$, $p > .35$)approaches. Finally, There was no interaction between gender and testing occasion with either the multivariate test ($\Lambda = 0.93$, $F_{2,25} < 1$, $p > .40$) or the univariate test ($F_{2,52} = < 1$, $p > .50$) (Appendix L.1).

Jita (Absolute Jitter in us)

Examination of the measure Jita of the sung /ɑ/ vowel indicated that the assumption of homogeneity of variance-covariance matrices over the three occasions between males and females was met. However, the sphericity assumption was not met. Therefore, the multivariate approach was used to

examine Jita. Analysis determined that both main effects for gender and occasion were present for the dependent variable Jita.

There was a significant difference between males and females of the variable Jita ($F_{1,26} = 19.91$, $p < .001$). Males scored significantly higher than did females by almost two standard deviations. The value of eta squared indicated that 43% of the variability pooled over occasions was aligned with gender. The most dramatic effect tested was that of occasion. Wilks' Lambda ($\Lambda = 0.52$, $F_{2,25} = 11.58$, $p < .001$) indicated that there was a significant difference over the testing occasion (the repeated measures). The proportion of variance of Jita of sung /ɑ/ pooled over genders was 48% whereas the power of this test was 0.99. The strength of variability indicates that the strongest effect of variability coincides with test occasion. From the independent trend components, a significant downward linear trend over the three testing occasions ($F_{1,26} = 16.09$, $p < .001$) and a significant positive quadratic component over the three testing occasions ($F_{1,26} = 18.27$, $p < .001$) was found. The two components were nearly equivalent in strength (41% vs. 38%) and their power ratings were equal. The downward linear trend indicates that Jita decreased over time. The positive quadratic component indicates that although Jita decreased over time, it bottomed out and slightly increased from occasion two to occasion three. These two components of trend reflect a dramatic training effect over time.

Finally, no interaction between gender and occasion was detected ($\Lambda = 0.98$, $F_{2,25} < 1$, $p > .75$). Although both gender and occasion are relatively strong effects (43% and 48%), the training program appears to be about 10% more important than gender in examining the variability in Jita of sung /ɑ/.

The results of the univariate approach support the results of the multivariate approach with comparable power shared by the two techniques. The differences over occasion have a value of eta squared of 39% compared with

43% aligned with gender. Regardless of technique, both gender and testing occasion are dramatic effects (Appendix L.2).

Jitt (Jitter Percent)

Examination of the measure Jitt of the sung /ɑ/ vowel indicated that the assumption of homogeneity of variance-covariance matrices over the three occasions between males and females was not met. However, the sphericity assumption was met. Therefore, both the univariate and the multivariate approaches were used to examine Jitt. Analysis determined that the main effect of occasion was present for the dependent variable Jitt.

There was no difference between males and females of the variable Jitt ($F_{1,26} = 2.86$, $p > .10$). Wilks' Lambda ($\Lambda = 0.50$) indicated that there was a significant difference over the occasions ($F_{2,25} = 12.63$, $p < .001$). The value of eta squared for occasion revealed that 50% of the variability (power = 0.99) in Jitt of sung /ɑ/ was aligned with the testing occasion (the repeated measures). From the transformed trend variables used in the multivariate test, both a significant downward linear trend over the three testing occasions ($F_{1,26} = 22.00$, $p < .001$) and a significant positive quadratic component over the three testing occasions ($F_{1,26} = 14.57$, $p < .001$) was found. The downward linear trend is 10% stronger than the positive quadratic component (46% vs. 36%); however, the power rating is almost equal (.99 to .96). The downward linear trend indicates that Jitt decreased over time. The positive quadratic component indicates that although Jitt decreased over time, it bottomed out and slightly increased from occasion two to occasion three. These two components of trend reflect a dramatic training effect over time.

The results of the univariate approach support the results of the multivariate approach. Finally, there was no interaction between gender and

testing occasion using either the univariate ($F_{2,52} = 1.32$, $p > .25$) or multivariate ($\Lambda = 0.93$, $F_{2,25} = 0.90$, $p > .40$) approach (Appendix L.3).

RAP (Relative Average Perturbation)

Examination of the measure RAP of the sung /ɑ/ vowel indicated that the assumption of homogeneity of variance-covariance matrices across the three occasions between males and females was not met. However, the sphericity assumption was met. Therefore, the multivariate approach was used to examine RAP. Analysis determined that both main effects, that of gender and occasion, were present for the dependent variable RAP.

There was a significant difference between males and females of the variable RAP ($F_{1,26} = 7.82$, $p < .01$); males scored significantly lower than females by at least a standard deviation pooling over occasions.. The value of eta squared indicated that 23% of the variability in RAP of sung /ɑ/, pooled over occasions, was aligned with gender. The most dramatic effect tested was that of occasion. Wilks' Lambda ($\Lambda = 0.49$) indicated that there was a significant difference over the occasions ($F_{2,25} = 12.87$, $p< .001$). Although 23% of the variability in RAP of sung /ɑ/ was aligned with gender, the value of eta squared for occasion revealed that 51% of the variability was aligned with the testing occasion (the repeated measures). The ratio of more than 2:1 in strength of variability indicates that the strongest effect of variability coincides with test occasion pooling over genders. From the transformed variables, a significant downward linear trend over the three testing occasions, and a significant positive quadratic component over the three testing occasions are found. The downward linear trend is 9% stronger than the positive quadratic component (46% vs. 35%); however, the power associated with each of the two tests is almost equal (.99 to .95). The downward linear trend indicates that RAP decreased over time. The positive quadratic component

indicates that although RAP decreased over time, it bottomed out and slightly increased from occasion two to occasion three. These two components of trend reflect a dramatic training effect over time.

The results of the univariate approach, for the occasion repeated measure ($F_{2,52} = 19.09$, $p < .001$), support the results of the multivariate approach. Finally, Wilks' Lambda ($\Lambda = .94$) indicated that there was no interaction between gender and testing occasion ($F_{2,25} = 0.69$, $p > .50$). The univariate approach also supports these results ($F_{2,52} = 1.03$, $p > .35$) (Appendix L.4).

PPQ (Pitch Perturbation Quotient)

This measure, PPQ of the sung /a/ vowel, is functionally related to the previous measure (RAP of sung vowel /a/) and therefore should exhibit similar assumption fitting characteristics. As anticipated, the assumption of homogeneity of variance-covariance matrices over the three occasions between males and females was not met. However, the sphericity assumption was met. Therefore, the multivariate approach was used to examine PPQ. Analysis determined that both main effects, that of gender and occasion were present for the dependent variable PPQ.

There was a significant difference between males and females of the variable PPQ ($F_{1,26} = 6.70$, $p < .02$); not surprisingly, the males scored approximately a standard deviation lower than did females. The value of eta squared indicated that 21% of the variability in PPQ of sung /a/, pooled over the three occasions, was aligned with gender. The most dramatic effect tested was that of occasion. Wilks' Lambda ($\Lambda = 0.47$) indicated that there was a significant difference over the occasions ($F_{2,25} = 13.02$, $p < .01$). Although 21% of the variability in PPQ of sung /a/ was aligned with gender, the value of eta squared for occasion revealed that 52% of the variability (power = 1.0) was aligned with

the testing occasion (the repeated measures). The ratio of more than 2:1 in strength of variability indicates that the stronger of the two effects coincides with test occasion. From the transformed variables, a significant downward linear trend over the three testing occasions ($F_{1,26} = 24.98, p < .001$) and a significant positive quadratic component over the three testing occasions ($F_{1,26} = 15.60, p < .001$) are found. The downward linear trend is 9% stronger than the positive quadratic component (49% vs. 38%); however, the power associated with the two tests is almost equal (1.0 to .97). The downward linear trend indicates that PPQ decreased over time. The positive quadratic component indicates that although PPQ decreased over time, it bottomed out and slightly increased from occasion two to occasion three. These two components of trend reflect a dramatic training effect over time.

The results of the univariate approach ($F_{2,52} = 20.98, p < .001$) of the repeated measures over occasions supported the results of the multivariate approach.

Finally, Wilks' Lambda ($\Lambda = .93$) indicated that there was no interaction between gender and testing occasion ($F_{2,25} = 1.00, p > .38$). Again, the results of the univariate approach ($F_{2,52} = 1.49, p > .20$) supported the multivariate approach (Appendix L.5).

sPPQ (Smoothed Pitch Perturbation Quotient)

Examination of the measure sPPQ of the sung /ɑ/ vowel indicated that the assumption of homogeneity of variance-covariance matrices over the three occasions between males and females was met. However, the sphericity assumption was not met. Therefore, the multivariate approach was used to examine PPQ. Analysis determined that both main effects, that of gender and occasion were present for the dependent variable sPPQ.

There was a significant difference between males and females of the variable sPPQ ($F_{2,25} = 9.17$, $p < .01$). Males scored at least a standard deviation higher than did females. The value of eta squared indicated that 26% of the variability, pooled over occasion, was aligned with gender. The most dramatic effect tested was that of occasion. Wilks' Lambda ($\Lambda = 0.47$) indicated that there was a significant difference over the occasions ($F_{2,25} = 14.22$, $p < .001$). The effect for testing occasion (eta squared = 53%) was twice as strong as the effect for gender. From the transformed trend variables, a significant downward linear trend ($F_{1,26} = 15.83$, $p < .001$) over the three testing occasions and a significant positive quadratic trend ($F_{1,26} = 23.56$, $p < .001$) over the three testing occasions are found. The positive quadratic component is stronger than the downward linear trend (47% vs. 38%); both trends have nearly equivalent power (1.0 to .97). The downward linear trend indicates that sPPQ decreased over time. The positive quadratic component indicates that although sPPQ decreased over time, it bottomed out and slightly increased from occasion two to occasion three. These two components of trend reflect a dramatic training effect over time.

The results of the univariate repeated measures approach ($F1.55, 40.41 = 18.01$, $p < .001$) support the results of the multivariate approach. Wilks' Lambda ($\Lambda = 0.90$) indicated that there was no interaction between gender and testing occasion ($F_{2,25} = 1.34$, $p > .25$) (Appendix L.6).

vFo (Fundamental Frequency Variation)

Examination of the measure vFo of the sung /ɑ/ vowel indicated that both assumptions of homogeneity of variance-covariance matrices of the three occasions between males and females and sphericity were met. Therefore, the univariate approach was used to examine vFo. Analysis determined that the main effect of occasion was present for the dependent variable vFo.

There was no difference between males and females of the variable vFo ($F_{1,26} < 1$, $p > .40$). A dramatic effect tested was that of occasion. There was a significant difference over the occasions ($F_{2,52} = 24.09$, $p < .001$). The value of eta squared for occasion revealed that approximately half of the variability (48% with a power of 1.0), pooled over genders, was aligned with the testing occasion (the repeated measures). From the transformed trend variables, a significant downward linear trend ($F_{1,26} = 23.57$, $p < .001$) over the three testing occasions and a significant positive quadratic trend ($F_{1,26} = 25.10$, $p < .001$) over the three testing occasions are found. The two independent trend variables are equal in strength (47% and 49% respectively). The power rating of these two tests is 0.99. The downward linear trend indicates that vAm decreased over time. The positive quadratic component indicates that although vAm decreased over time, it bottomed out and slightly increased from occasion two to occasion three. These two components of trend reflect a dramatic training effect over time. Finally, there was no interaction between gender and testing occasion ($F_{2,52} = 2.61$, $p > .08$) (Appendix L.7).

Amplitude Measures

ShdB (Shimmer in decibels)

Examination of the measure ShdB of the sung /ɑ/ vowel indicated that the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions was met. However, the sphericity assumption was not met. Therefore, the multivariate approach was used to examine ShdB. Analysis determined that all three effects were present: gender and occasion separately and the interaction effect of gender with occasion.

There was a significant difference between males and females on the variable ShdB ($F_{1,26} = 4.81$, $p < .05$). The value of eta squared indicated that

16% of the variability pooled over occasions was aligned with gender. The most dramatic effect tested was that of occasion. Wilks' Lambda indicated that there was a significant difference over the occasions ($\Lambda = 0.25$, $F_{2,25} = 38.49$, $p < .001$). This proportion of the variability in ShdB of sung /a/ was aligned with the interaction of gender and occasion and represents less than 1/3 of that aligned with testing occasion. The eta squared for occasion revealed that 75% of the variability in ShdB of sung /ɑ/, pooled over gender, was aligned with the testing occasion (the repeated measures). The ratio more than 3:1 in strength of variability indicates that the strongest effect of variability coincides with test occasion. From the transformed trend variables, a significant downward linear trend ($F_{1,26} = 69.66$, $p < .001$) over the three testing occasions and a significant positive quadratic trend ($F_{1,26} = 65.48$, $p < .001$) over the three testing occasions were found. The two independent trend variables are effectively of the same strength; the power of the tests is 1.0. The downward linear trend indicates that ShdB decreased over time. The positive quadratic component indicates that although ShdB decreased over time, it bottomed out and slightly increased from occasion two to occasion three. These two components of trend reflect a dramatic training effect over time.

Wilks' Lambda for the interaction effect indicated that males differed from females by differing amounts over occasions ($\Lambda = 0.79$, $F_{2,25} = 3.33$, $p < .05$). The value of eta squared revealed that 21% of the variability in ShdB was aligned with the interaction of gender and test occasion.

The results of the univariate approach support the results of the multivariate approach but with more power. This change in power is due to the increase in estimates required by the multivariate approach with a small sample size of 28 subjects (Appendix M.1).

Shim (Shimmer Percent)

Examination of the measure Shim of the sung /ɑ/ vowel indicated that the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions was met. However, the sphericity assumption was not. Therefore, the multivariate approach was used to examine Shim. Analysis determined that main effects for both gender and occasion and the interaction of gender with occasion were all present for the dependent variable Shim.

There was a significant difference between males and females of the variable Shim ($F_{1,26} = 5.36$, $p < .03$), with males being higher by at least a standard deviation over females. The value of eta squared indicated that 17% of the variability, pooled over occasion, was aligned with gender. The most dramatic effect tested was that of occasion. Wilks' lambda indicated that there was a significant difference over the occasions ($\Lambda = 0.25$, $F_{2,25} = 37.48$, $p < .001$). The eta squared value for occasion revealed that 75% of the variability in Shim of sung /a/, pooled over gender, was aligned with the testing occasion (the repeated measures). From the transformed trend variables, a significant downward linear trend ($F_{1,26} = 70.25$, $p < .001$) over the three testing occasions and a significant positive quadratic trend ($F_{1,26} = 61.27$, $p < .001$) over the three testing occasions were found. The two independent trend variables are equal in strength (approximately 70%); each with a power rating of 1.0. The downward linear trend indicates that Shim decreased over time. The positive quadratic component indicates that although Shim decreased over time, it bottomed out and slightly increased from occasion two to occasion three. These two components of trend reflect a dramatic training effect over time.

Wilks' Lambda for the interaction effect indicated that males differed from females by differing amounts over occasions ($\Lambda = 0.75$, $F_{2,25} = 4.08$, $p < .03$).

The value of eta squared revealed that 25% of the variability of Shim was aligned with the interaction of gender and test occasion. 25% of the variability in Shim of sung /ɑ/ was aligned with the interaction of gender and occasion, whereas 75% was aligned with the occasion effect. The ratio of 3:1 in strength of variability indicates that the strongest effect of variability coincides with test occasion.

The results of the univariate approach support the results of the multivariate approach but with more power. This change in power is due to the increase in estimates required by the multivariate approach with a small sample size of 28 subjects (Appendix M.2).

APQ (Amplitude Perturbation Quotient)

Examination of the measure APQ of the sung /ɑ/ vowel indicated that the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions was detected. However, the sphericity assumption was not met. Therefore, the multivariate approach was used to examine APQ. Analysis determined that the main effects for gender and occasion, as well as the interaction of gender with occasion were all present for the dependent variable APQ.

There was a significant difference between males and females of the variable APQ ($F_{1,26} = 5.78$, $p < .03$). Males scored significantly higher than females. The value of eta squared indicated that 18% of the variability, pooled over occasions, was aligned with gender. The most dramatic effect tested was that of occasion. Wilks' Lambda indicated that there was a significant difference over the occasions ($\Lambda = 0.17$, $F_{2,25} = 59.26$, $p < .001$). The eta squared value for occasion revealed that 83% of the variability in APQ of sung /ɑ/, pooled over gender, was aligned with the testing occasion (the repeated measures). This value represents about 1/3 of strength of effect associated with the occasion effect. A

significant downward linear trend ($F_{1,26} = 93.95$, $p < .001$) over the three testing occasions and a significant positive quadratic trend ($F_{1,26} = 101.73$, $p < .001$) over the three testing occasions was found. The two independent trend variables are nearly of equal strength (linear trend 78%, quadratic component 80%). The power of each test was 1.0. The downward linear trend indicates that APQ decreased over time. The positive quadratic component indicates that although APQ decreased over time, it bottomed out and slightly increased from occasion two to occasion three. These two components of trend reflect a dramatic training effect over time.

Wilks' Lambda for the interaction effect indicated that males differed from females by differing amounts over occasions ($\Lambda = 0.74$, $F_{2,25} = 4.32$, $p < .03$). The value of eta squared revealed that 26% of the variability in APQ was aligned with the interaction of gender and test occasion.

The results of the univariate approach support the results of the multivariate approach, but with more power. This change in power is owed to the increase in estimates required by the multivariate approach with a small sample size of 28 subjects (Appendix L.3).

sAPQ (Smoothed Amplitude Perturbation Quotient)

Examination of the measure sAPQ of the sung /ɑ/ vowel indicated that neither the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions, nor the sphericity assumption was met. Therefore, the multivariate approach was used to examine sAPQ. Analysis determined that the main effect of gender was present for the dependent variable sAPQ.

There was no difference between males and females of the variable sAPQ ($F_{1,26} < 1$, $p > .80$). Wilks' Lambda indicated that there was a significant

difference over occasions (Λ = 0.25, $F_{2,25}$ = 37.64, p < .001). The value of eta squared revealed that 75% (power =1.0) of the variability in sAPQ of sung /ɑ/, pooled over gender, was aligned with the testing occasion (the repeated measures). A significant downward trend ($F_{1,26}$ = 52.14, p < .001) over the three testing occasions and a significant positive quadratic trend ($F_{1,26}$ = 64.18, p < .001) over the three testing occasions were found. The two independent trend variables are equal in power (both 1.0), however, the quadratic component is slightly stronger (67% - 71%). The downward linear trend linear trend indicates that sAPQ decreased over time. The positive quadratic component indicates that although sAPQ decreased over time, it bottomed out and slightly increased from occasion two to occasion three. These two components of trend reflect a dramatic training effect over time. Finally, there was also no interaction effect between gender and occasion (Λ = 0.98, $F_{2,25}$ < 1, p > .70) (Appendix M.4).

vAm (Peak-Amplitude Variation)

Examination of the measure vAm of the sung /ɑ/ vowel indicated that neither the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions, nor the sphericity assumption was met. Consequently, the multivariate approach was used to examine vAm. Analysis determined that main effects for both gender and occasion were present for the dependent variable vAm.

There was a significant difference between males and females of the variable vAm ($F_{1,26}$ = 8.08, p < .01). Males scored more than a standard deviation (significantly) lower than did females. The value eta squared indicated that 24% of the variability pooled over occasion was aligned with gender. The most dramatic effect tested was that of occasion. Wilks' Lambda indicated that there was significant difference over the occasions (Λ = 0.42, $F_{2,25}$ = 17.33, p <

.001). The eta squared value for occasion revealed that 58% (power = 1.0) of the variability in vAm of sung /ɑ/, pooled over gender, was aligned with the testing occasion (the repeated measures). This represents more than twice the strength of effect for the gender effect. A significant downward linear trend ($F_{1,26}$ = 31.77, $p < .001$) over the three testing occasions, and a significant positive quadratic trend ($F_{1,26}$ = 31.53, $p < .001$) over the three testing occasions were found. The two independent trend components are equal in strength; the power of each test was 0.99. The downward linear trend indicates that vAm decreased over time. The positive quadratic component indicates that although vAm decreased over time, it bottomed out and slightly increased from occasion two to occasion three. These two components of trend reflect a dramatic training effect over time. Finally, there was no significant interaction between occasion and gender ($\Lambda = 0.92$, $F_{2,25} = 1.08$, $p > .30$) (Appendix M.5).

Noise Related Measures

NHR (Noise to Harmonic Ratio)

Examination of the measure NHR of the sung /ɑ/ vowel indicated that the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions was not met. However, the assumption of sphericity was met. Therefore, the Univariate approach was used to examine NHR. Analysis determined that the main effect of gender was present for the dependent variable NHR.

There was a significant difference between males and females of the variable NHR ($F_{1,26}$ = 11.96, $p < .01$). The males average NHR was significantly higher by at least a standard deviation above the females. The value of eta squared indicated that 32% of the variability was aligned with gender (power rating = .91). There was no difference over occasions ($F_{2,52} < 1$, $p > .50$). There

was also no interaction effect between gender and occasion ($F_{2,52} = 2.69$, $p > .05$). The multivariate approach also reports that there is no significant difference over occasions. However, Wilks' Lambda revealed that there is a significant interaction between gender and occasion ($\Lambda = 0.77$, $F_{2,25} = 3.78$, $p < .04$). The value of eta squared indicated that 23% of the variability in NHR of sung /ɑ/ was aligned with the interaction between gender and testing occasion (the repeated measures). Although the multivariate approach indicated an interaction between gender and the testing occasion, the power rating is only 0.63 which indicates that it is due to not much more than chance (Appendix N.1).

VTI (Voice Turbulence Index)

To examine the measure VTI of the sung /ɑ/ vowel, it was first necessary to determine whether the following assumptions could be met: homogeneity between males and females of variance-covariance matrices over the three occasions and sphericity (i.e., is there congruity from element to element). The assumption of sphericity was met. Therefore, the Univariate approach was used to examine VTI. Analysis determined that no main effect was present for the dependent variable VTI.

There was no difference between males and females of the variable VTI ($F_{1,26} = 2.18$, $p > .15$). There was no difference over occasions ($F_{2,52} < 1$, $p > .70$). No interaction effect between gender and occasion was found. The multivariate approach also reports that there is no significant difference over occasions and no significant interaction between gender and occasion (Appendix N.2).

SPI (Soft Phonation Index)

Examination of the measure SPI of the sung /ɑ/ vowel indicated that the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions was not met. However, the assumption of sphericity was met. Therefore, the univariate approach was used to examine SPI. Analysis determined that the main effect of occasion was present for the dependent variable SPI.

There was no difference between males and females of the variable SPI ($F_{1,26} < 1$, $p > .50$), but there was a significant difference over occasions ($F_{2,52} = 13.17$, $p < .001$). The value of eta squared indicated that 33% of the variability in SPI of sung /ɑ/, pooled over gender, (power rating = 1.0) was aligned with testing occasion (the repeated measures). The multivariate approach, using Wilks' Lambda, also indicated that there was a significant difference over occasions. The value of eta squared indicated that 50% of the variability in SPI of sung /ɑ/ was aligned with the testing occasion (the repeated measures). Eta squared is much larger using the multivariate approach, and the power rating is equal to that of the univariate approach (1.0). A significant downward linear trend ($F_{1,26} = 24.71$, $p < .001$) over the three testing occasions was found. The downward linear trend indicates that SPI decreased over time. This component of trend reflects a dramatic training effect over time. There was also no interaction effect between gender and occasion ($F_{2,52} = 1.21$, $p > .30$) (Appendix N.3).

Tremor Related Measures

Ftri (F_0 Tremor Intensity Index)

For the measure Ftri of the sung /ɑ/ vowel, the assumption of homogeneity of variance-covariance matrices over the three occasions between males and females was met. However, the sphericity assumption was not.

Therefore, the multivariate approach was used to examine Ftri. Analysis determined that the main effect of occasion was present for the dependent variable Ftri.

There was no difference between males and females of the variable Ftri ($F_{1,26} = 2.12$, $p > .08$). Wilks' Lambda indicated that there was a significant difference over the occasions ($\Lambda = 0.57$, $F_{2,25} = 9.53$, $p < .001$). The value of eta squared for occasion revealed that 43% of the variability of the dependent variable pooled over genders was aligned with the testing occasion (the repeated measures). The power associated with this test was 0.96. From the transformed trend variables, there was a significant linear trend over the three testing occasions ($F_{1,26} = 5.89$, $p < .025$) and also a significant positive quadratic component over the three testing occasions ($F_{1,26} = 16.09$, $p < .001$). The positive quadratic component ($n^2 = .38$) was more than twice as strong as the linear component ($n^2 = .18$). The two independent trends indicate that Ftri decreased over time, bottomed out, and increased from occasion two to occasion three. This component of trend reflect a dramatic training effect over time.

Finally, there was no interaction between gender and testing occasion detected ($\Lambda = 0.89$, $F_{2,25} = 1.52$, $p > .20$). The conservative epsilon degrees of freedom adjustments in the univariate approach for analyzing repeated measures produced similar results. For the occasions effect F1.50, 39.12 = 8.12, $p < .01$, whereas for the interaction of gender and occasion F1.50, 39.12 < 1, $p > .40$ (Appendix O.1).

ATRI (Amplitude Tremor Intensity Index)

Examination of the measure ATRI of the sung /ɑ/ vowel indicated that neither the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions, nor the assumption of sphericity

was met. Therefore, the multivariate approach was used to examine vAm. Analysis determined that only the main effect of occasion was present for the dependent variable ATRI.

There was no significant difference between males and females of the variable ATRI ($F_{1,26} = 3.32$, $p > .05$). Wilks' Lambda indicated that there was a significant difference over occasions ($\Lambda = 0.59$, $F_{2,25} = 8.62$, $p < .001$). The value of eta squared revealed that 40% (power = .95) of the variability in ATRI of sung /ɑ/, pooled over gender, was aligned with the testing occasion (the repeated measures). A significant downward trend ($F_{1,26} = 14.66$, $p < .001$) over the three testing occasions and a significant positive quadratic trend ($F_{1,26} = 14.41$, $p < .001$)over the three testing occasions were found. The two independent trend variables were nearly of equal strength (36%) and the power of the tests was equal. There was also no interaction effect between gender and occasion ($\Lambda = 0.94$, $F_{2,25} < 1$, $p > .50$) (Appendix O.2).

Fftr (F_oTremor Frequency)

Examination of the measure Fftr of the sung /ɑ/ vowel indicated that there was homogeneity of variance between the males and females over the three occasions, but the covariances were not all homogeneous. Moreover, the sphericity assumption was met. Therefore, the univariate approach was used to examine Fftr. Analysis determined that the main effect of occasion was present for the dependent variable Fftr.

There was no difference between males and females of the variable Fftr ($F_{1,26} < 1$, $p > .40$). There was a significant difference over testing occasions ($F_{2,52} = 9.63$, $p < .001$). The value of eta squared for occasions revealed that 27% of the variability in Fftr of sung /ɑ/, pooled over genders, was aligned with the testing occasion (the repeated measures). Where the independent trend

components were tested, only a significant downward linear trend ($F_{1,26} = 18.21$, $p < .001$) over the three testing occasions was found . The downward linear trend indicates that Fftr decreased over time. This component of trend reflects a dramatic training effect over time. Finally, there was no interaction between gender and testing occasion ($F_{2,52} = 1.98$, $p > .15$) (Appendix O.3).

Fatr (Amplitude Tremor Frequency)

Examination of the measure Fatr of the sung /ɑ/ vowel indicated that the variances were homogeneous between males and females over the three occasions; however, the covariance matrices were not homogeneous. The assumption of sphericity was met. Therefore, the Univariate approach was used to examine Fatr. Analysis determined that the main effect of occasion was present for the dependent variable Fatr.

There was no difference between males and females of the variable Fatr ($F_{1,26} < 1$, $p > .75$). There was a significant difference over occasions ($F_{2,52} = 5.02$, $p < .01$). The value of eta squared revealed that 16% of the variability (power = .79) in Fatr of sung /ɑ/, pooled over gender, was aligned with the testing occasion (the repeated measures). The multivariate approach also reported that there is a significant difference over occasions. Wilks' Lambda revealed that there is a significant difference over occasions. The value of eta squared indicated that 25% of the variability in Fatr of sung /ɑ/ was aligned with the testing occasion (the repeated measures). Although the multivariate approach indicated a higher percent of the variability aligned with the testing occasion, the power is .69 instead of .80. The univariate approach more strongly revealed that it is due to greater than chance that 17% of the variability is aligned with the testing occasion. There was also no interaction effect between gender and occasion

($F_{2,52}$ = 2.57, p > .08). A significant linear trend over occasions was detected ($F_{1,26}$ = 7.96, p < .01) (Appendix O.4).

Spoken Phonation of the /i/ vowel

Fundamental Frequency Measures

F_o (Fundamental Frequency)

Examination of the measure F_O of the spoken /i/ vowel indicated that neither the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions, nor sphericity was met. Therefore, the multivariate approach was used to examine F_O. Analysis determined that both main effects, that of gender and occasion, were present for the dependent variable F_O.

There was a significant difference between males and females of the variable F_O ($F_{1,26}$ = 69.33, p < .001). The value of eta squared indicated that 73% of the variability pooled over occasion was aligned with gender. The power of the test was 1.0. Wilks' Lambda (Λ = .066) indicated that there was a significant difference over testing occasions ($F_{2,25}$ = 0.66, p < .01). The effect for gender (eta squared = 73%) was twice as strong as the effect for testing occasion (eta squared = 34%). There was no significant linear trend ($F_{1,26}$ = 1.99, p > .15); however, there was a significant quadratic component open upward over the three testing occasions ($F_{1,26}$ = 12.74, p < .001). This reflects a dramatic training effect over time.

There was no interaction gender over testing occasions (Λ = 0.80, $F_{2,25}$ = 3.15, p > .05) . The univariate approach supported the results of the multivariate approach (Appendix P.1).

Jita (Absolute Jitter in us)

Examination of the measure Jita of the spoken /i/ vowel indicated that both assumptions of homogeneity between males and females of variance-covariance matrices over the three occasions and sphericity were met. Therefore, the univariate approach was used to examine Jita. Analysis determined that the main effect of occasion was present for the dependent variable Jita.

There was no difference between males and females of the variable Jita ($F_{1,26} < 1$, $p > .80$), but there was a significant difference over testing occasions ($F_{2,52} = 9.19$, $p < .001$). The value of eta squared indicated that 26% of the variability in Jita of spoken /i/, pooled over gender, was aligned with testing occasion (the repeated measures). The power of the test was 0.96. There was no interaction between gender over testing occasions ($F_{2,52} < 1$, $p > .50$). A significant downward linear trend ($F_{1,26} = 10.74$, $p < .01$) and a significant quadratic component ($F_{1,26} = 6.98$, $p < .02$) over the three testing occasions was found. This combination of trends indicated a J-shaped pattern over the duration of the training program and indicates a dramatic training effect over time (Appendix P.2).

Jitt (Jitter Percent)

Examination of the measure Jitt of the spoken /i/ vowel indicated that both assumptions of homogeneity between males and females of variance-covariance matrices over the three occasions and sphericity were met. Therefore, the univariate approach was used to examine Jitt. Analysis determined that both main effects, that of gender and occasion, were present for the dependent variable Jitt.

There was a significant difference between males and females of the variable Jitt ($F_{1,26} = 10.31$, $p < .005$). The value of eta squared indicated that

28% of the variability in Jitt of spoken /i/, pooled over occasion, was aligned with gender. The power of the test was 0.87. There was a significant difference over testing occasions ($F_{2,52} = 17.55$, $p < .001$). The value of eta squared indicated that 40% of the variability in Jitt of spoken /i/, pooled over gender, was aligned with testing occasion (the repeated measures). The power of the test was 1.0. The more dramatic effect was that of occasion; it was stronger than gender by a ratio of almost 2:1. Both a significant downward linear trend ($F_{1,26} = 20.31$, $p < .001$) and a significant quadratic trend open upward ($F_{1,26} = 13.16$, $p < .001$) were found. These trends indicate that in general, Jitt decreased over time and exhibited a slight J-shaped pattern. The ratio of strengths of the two effects is 4:3 (44% to 33%). Together they reveal a dramatic training effect over time.

There was no interaction between gender over testing occasions ($F_{2,52} = 2.94$, $p > .05$) (Appendix P.3).

RAP (Relative Average Perturbation)

Examination of the measure RAP of the spoken /i/ vowel indicated that both assumptions of homogeneity between males and females of variance-covariance matrices over the three occasions and sphericity were met. Therefore, the univariate approach was used to examine RAP. Analysis determined that both main effects, that of gender and occasion, were present for the dependent variable RAP.

There was a significant difference between males and females of the variable RAP ($F_{1,26} = 11.16$, $p < .005$). The value of eta squared indicated that 30% of the variability in RAP of spoken /i/, pooled over occasion, was aligned with gender. The power rating of the test was 0.89. There was a significant difference over testing occasions ($F_{2,52} = 17.59$, $p < .001$). The value of eta squared indicated that 40% of the variability in Jitt of spoken /i/, pooled over

gender, was aligned with testing occasion (the repeated measures). The power rating of the test was 1.0. The more dramatic effect was that of occasion being stronger than gender by 10%. A significant downward linear trend over the three testing occasions ($F_{1,26}$ = 19181, $p < .001$) and a positive quadratic component over the three testing occasions ($F_{1,26}$ = 13.86, $p < .001$) were found. The linear trend was stronger than the quadratic trend (43% - 34%); the power of the two tests was almost equivalent (0.98 - 0.94). The significant downward linear trend indicates that RAP decreased over time. The positive quadratic component indicates that although RAP decreased over time it bottomed out and increased from occasion two to occasion three. These two independent components of trend reflect a dramatic training effect over time.

There was no interaction between gender over testing occasions ($F_{2,52}$ = 2.98, $p > .06$) (Appendix P.4).

PPQ (Pitch Perturbation Quotient)

Examination of the measure PPQ of the spoken /i/ vowel indicated that both assumptions of homogeneity between males and females of variance-covariance matrices over the three occasions and sphericity were met. Therefore, the univariate approach was used to examine PPQ. Analysis determined that both main effects, that of gender and occasion, were present for the dependent variable PPQ.

There was a significant difference between males and females of the variable PPQ ($F_{1,26}$ = 10.85, $p < .005$). The value of eta squared indicated that 29% of the variability in PPQ of spoken /i/, pooled over occasion, was aligned with gender. The power of the test was 0.88. There was a significant difference over testing occasions ($F_{2,52}$ = 17.58, $p < .001$). The value of eta squared indicated that 40% of the variability in PPQ of spoken /i/, pooled over gender, was aligned

with testing occasion (the repeated measures). The power of the test was 1.0. The more dramatic effect was that of occasion being stronger than gender by 11%. There was no significant interaction between gender over testing occasions ($F_{2,52} = 3.11$, $p > .05$). From the transformed variables, a significant downward linear trend over the three testing occasions ($F_{1,26} = 21.08$, $p < .001$) and a significant open upward quadratic trend ($F_{1,26} = 12.36$, $p < .005$) were found. The significant downward linear trend indicates that PPQ decreased over time, whereas the open upward quadratic trend suggests an asymptotic downward wave. The ratio of strengths of effect are 45% to 32%. These components of trend reflect a dramatic training effect over time (Appendix P.5).

sPPQ (Smoothed Pitch Perturbation Quotient)

Examination of the measure sPPQ of the spoken /i/ vowel indicated that both assumptions of homogeneity between males and females of variance-covariance matrices over the three occasions and sphericity were met. Therefore, the univariate approach was used to examine sPPQ. Analysis determined that both main effects, that of gender and occasion, as well as the interaction between gender and occasion were all present for the dependent variable sPPQ.

There was a significant difference between males and females of the variable sPPQ ($F_{1,26} = 4.60$, $p < .05$). The value of eta squared indicated that 15% of the variability in sPPQ of spoken /i/, pooled over occasion, was aligned with gender. The power of the test was approximately at chance level (0.54). The more dramatic effect was occasion. Whereas 15% of the variability was aligned with gender, 39% of the variability was aligned with testing occasion (the repeated measures). The power of the test was 1.0. The effect was stronger by a ratio of more than 2:1 to that of gender and almost 4:1 to that of the interaction between gender and occasion. Both a significant downward linear trend over the three

testing occasions ($F_{1,26} = 18.11$, $p < .001$) and a significant open upward quadratic trend were found. The strengths of the two effects are 41% to 34%. The significant downward linear and open upward quadratic trends indicate that sPPQ decreased over time in an asymptotic fashion. These components of trend reflect a dramatic training effect over time.

There was a significant interaction between gender and testing occasions ($P < .05$). The value of eta squared indicated that 11% of the variability (power rating = .60) in sPPQ of spoken /i/ was aligned with the interaction between gender and testing occasion (the repeated measures) (Appendix P.6).

vFo (Fundamental Frequency Variation)

Examination of the measure vFo of the spoken /i/ vowel indicated that both assumptions of homogeneity between males and females of variance-covariance matrices over the three occasions and sphericity were met. Therefore, the univariate approach was used to examine vFo. Analysis determined that both main effects, that of gender and occasion, were present for the dependent variable vFo.

There was a significant difference between males and females of the variable vFo ($F_{1,26} = 4.53$, $p < .05$). The value of eta squared indicated that 15% of the variability in vFo of spoken /i/, pooled over occasion, was aligned with gender. The power of the test was close to chance (0.53). A more dramatic effect was that of occasion ($F_{2.52} = 14.90$, $p < .001$). Although 15% of the variability was aligned with gender, more than twice the amount, 36%, of the variability was aligned with testing occasion (the repeated measures). The power of the test was 1.0. A significant downward linear trend ($F_{1,26} = 18.57$, $p < .001$) over the three testing occasions was found. In addition, a significant open upward quadratic trend was found ($F_{1,26} = 9.10$, $p < .01$). The ratio of the strengths of effect (41%

to 26%) represents a 3 to 2 proportion between the linear and quadratic trend. This suggests an asymptotic downward pattern. These components of trend reflect a dramatic training effect over time.

There was no interaction between gender and testing occasions ($F_{2,52} = < 1$, $p > .30$) (Appendix P.7).

Amplitude Measures

ShdB (Shimmer in decibels)

Examination of the measure ShdB of the spoken /i/ vowel indicated that both assumptions of homogeneity between males and females of variance-covariance matrices over the three occasions and sphericity were met. Therefore, the univariate approach was used to examine ShdB. Analysis determined that no main effect was present for the dependent variable ShdB.

There was no difference between males and females of the variable ShdB ($F_{1,26} < 1$, $p > .30$). There was no difference over testing occasion (the repeated measures) ($F_{2,52} < 1$, $p > .60$). Finally, there was no interaction between gender and testing occasions ($F_{2,52} = < 1$, $p > .70$) (Appendix Q.1).

Shim (Shimmer Percent)

Examination of the measure Shim of the spoken /i/ vowel indicated that both assumptions of homogeneity between males and females of variance-covariance matrices over the three occasions and sphericity were met. Therefore, the univariate approach was used to examine Shim. Analysis determined that no main effect was present for the dependent variable Shim.

There was no difference between males and females of the variable Shim ($F_{1,26} < 1$, $p > .30$). There was no difference over testing occasion (the repeated

measures) ($F_{2,52} < 1$, $p > .50$). Finally, there was no interaction between gender and testing occasions ($F_{2,52} < 1$, $p > .80$) (Appendix Q.2).

APQ (Amplitude Perturbation Quotient)

Examination of the measure APQ of the spoken /i/ vowel indicated that both assumptions of homogeneity between males and females of variance-covariance matrices over the three occasions and sphericity were met. Therefore, the univariate approach was used to examine APQ. Analysis determined that no main effect was present for the dependent variable APQ.

There was no difference between males and females of the variable APQ ($F_{1,26} < 1$, $p > .60$). There was no difference over testing occasion (the repeated measures) ($F_{2,52} < 1$, $p > .40$). Finally, there was no interaction between gender and testing occasions ($F_{2,52} = 1.40$, $p > .20$) (Appendix Q.3).

sAPQ (Smoothed Amplitude Perturbation Quotient)

Examination of the measure sAPQ of the spoken /i/ vowel indicated that the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions was met; however, the assumption of sphericity was not met. Therefore, the multivariate approach was used to examine sAPQ. Analysis determined that the main effect of occasion was present for the dependent variable sAPQ.

There was no difference between males and females of the variable sAPQ ($F_{1,26} < 1$, $p > .50$), and no interaction between gender and testing occasions was found ($p < .05$). Wilks' Lambda ($\Lambda = 0.68$, $F_{2,25} = 5.77$, $p < .01$) indicated that there was a significant difference over testing occasion (the repeated measures). The value of eta squared revealed that 31% of the variability pooled over gender was aligned with testing occasion. The power of this test was 0.82. A significant

downward linear trend ($F_{1,26} = 11.92$, $p < .001$) and significant open upward quadratic trend ($F_{1,26} = 8.05$, $p < .01$) were detected. The former was relatively stronger (0.31 to 0.24 eta squares) and was detected with greater power (0.91 to 0.78). The combination of trend indicated a decreasing asymptotic trend over the training program, a dramatic impact of the training (Appendix Q.4).

vAm (Peak-Amplitude Variation)

Examination of the measure vAm of the spoken /i/ vowel indicated that the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions was not met; however, the assumption of sphericity was met. Therefore, the multivariate approach was used to examine vAm. Analysis determined that the main effect of occasion was present for the dependent variable vAm.

Pooling over occasions, there was no difference between males and females of the variable vAm ($F_{1,26} = 1.32$, $p > .20$). Wilks' Lambda ($\Lambda = 0.66$, $F_{2,25} = 6.58$, $p < .01$) indicated that there was a significant difference over testing occasion (the repeated measures). The value of eta squared revealed that 35% of the variability pooled over gender was aligned with testing occasion. The power of this test was 0.87 indicating it was due to more than chance. When the trend was examined for linear and quadratic components, only a significant downward linear trend was found ($F_{1,26} = 12.94$, $p < .001$). The univariate approach supports the results of the multivariate approach but with more power. This change in power is owed to the increase in estimates required by the multivariate approach with a small sample size of 28 subjects.

Finally, there was no interaction between gender and testing occasions ($\Lambda = 0.84$, $F_{2,25} = 2.38$, $p > .10$) (Appendix Q.5).

Noise Related Measures

NHR (Noise to Harmonic Ratio)

Examination of the measure NHR of the spoken /i/ vowel indicated that there was homogeneity of variance between males and females at each of the three occasions; however, the variance-covariance matrices over the three occasions exhibited differing occasion to occasion correlations for males and females. When pooling over genders, the sphericity assumption was not met. Therefore, the univariate approach was used to examine NHR. Analysis determined that both main effects, that of gender and occasion, were present for the dependent variable NHR.

In pooling over gender, there was a significant difference between males and females of the variable NHR ($F_{1,26} = 11.01$, $p < .005$). The value of eta squared indicated that 30% of the variability pooled over occasion was aligned with gender. The power of the test was 0.90. In pooling over gender, there was a significant difference over testing occasion ($F_{2,52} = 6.51$, $p < .005$). The value of eta squared indicated that 20% of the variability in NHR of spoken /i/, pooled over gender, was aligned with testing occasion (the repeated measures). The more dramatic effect was that of gender being 10% stronger than that of testing occasion; both tests had equivalent power of 0.90. A significant downward linear trend ($F_{1,26} = 7.58$, $p < .02$) and significant open upward quadratic trend ($F_{1,26} = 4.88$, $p < .04$) were detected. The strength of the two trends were 23% and 16%, indicating an asymptotic pattern over the training program.

Finally, there was no interaction between gender and testing occasions ($F_{2,52} < 1$, $p > .80$) (Appendix R.1).

VTI (Voice Turbulence Index)

Examination of the measure VTI of the spoken /i/ vowel indicated that there was homogeneity of variance between males and females on each testing occasion; however, the occasion to occasion correlation differed for males and females. The assumption of sphericity was met. Therefore, the multivariate approach was used to examine VTI. Analysis determined that the main effect of gender and the interaction between gender and occasion were present for the dependent variable VTI.

There was no difference between males and females of the variable NHR ($F_{1,26} = 2.82$, $p > .10$). Wilks' Lambda ($\Lambda = 0.77$, $F_{2,25} = 3.71$, $p < .05$) indicated that there was a significant difference over testing occasion. The value of eta squared revealed that 23% of the variability in VTI of spoken /i/, pooled over gender, was aligned with testing occasion (the repeated measures). A significant downward linear trend ($F_{1,26} = 7.38$, $p < .02$) was detected. The strength of the effect was 22% (eta squared) . The power of the test was 0.74. Wilks' Lambda ($\Lambda = 0.78$, $F_{2,25} = 3.59$, $p < .05$) indicated that there was a significant interaction between gender and testing occasions. The value of eta squared indicated that 22% of the variability in VTI of spoken /i/ was aligned with the interaction between gender and testing occasion. These two effects are of nearly equivalent strength and power. The nature of the interaction was ordinal, males exceeding females; the widest difference was midway through the training program.

The univariate approach supports the results of the effect of testing occasion (with more power); however, it does not support the results of the interaction between gender and testing occasion. According to the univariate approach interaction between gender and occasion was not corroborated ($F_{2,52} = 2.63$, $p > .08$). The value of eta squared for the testing occasion was 17%; the power of the test was 0.83 (Appendix R.2).

SPI (Soft Phonation Index)

Examination of the measure SPI of the spoken /i/ vowel indicated that the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions was met; however, the assumption of sphericity was not met. Therefore, the multivariate approach was used to examine SPI. Analysis determined that the main effects, that of gender and occasion, as well as the interaction between gender and occasion, were all present for the dependent variable SPI.

Pooling over occasion, there was a significant difference between males and females of the variable SPI ($F_{1,26} = 7.84$, $p < .01$). The value of eta squared indicated that 23% of the variability in SPI of spoken /i/, pooled over occasion, was aligned with gender. The power of the test was 0.76. Wilks' Lambda ($\Lambda = 0.45$, $F_{2,25} = 15.01$) indicated that there was a significant difference over testing occasion. The value of eta squared revealed that 55% of the variability in SPI of spoken /i/, pooled over gender, was aligned with testing occasion (the repeated measures). The more dramatic effect was that of testing occasion with a ratio of more than 2:1 to either of the afore mentioned effects; having a power rating of 1.0 vs. .76 and .64 respectively. A significant downward linear trend over the three testing occasions ($F_{1,26} = 30.90$, $p < .001$) and a significant positive quadratic trend over the three testing occasions ($F_{1,26} = 16.57$, $p < .001$) were found. The linear trend was stronger than the quadratic trend (54% to 39%), however, the power of the two tests was nearly equivalent (.99 to .97). The downward linear trend indicates that SPI decreased over time. The positive quadratic component indicates that although SPI decreased over time, it bottomed out and slightly increased from occasion two to occasion three. These two independent components of trend reflect a dramatic asymptotic training effect over time.

Finally, Wilks' Lambda ($\Lambda = 0.76$, $F_{2,25} = 4.04$, $p < .05$) indicated that there was a significant interaction between gender and testing occasions. The value of eta squared that 24% of the variability was aligned with the interaction between gender and testing occasion. The nature of this interaction, termed on ordinal interaction, is a difference between males and females that progressively diminishes over occasions (Lubin, 1962).

The Greenhouse-Geisser univariate approach dramatically supports the results of the effect of testing occasion (F 1.21, 31.52 = 25.30, $p < .001$) but only marginally supporting the existence of an interaction between gender and testing occasion (F1.21, 31.52 = 3.80, $p < .05$). The 4:1 strength of the two effects bears this out; eta squared aligned with testing occasion is 49%, whereas eta squared for interaction is only 12%. The power of the two tests also favors the occasion effect over the interaction (1.0 to 0.67) (Appendix R.3).

Tremor Related Measures

Ftri (F_o Tremor Intensity Index)

Examination of the measure Ftri of the spoken /i/ vowel indicated that both assumptions of homogeneity between males and females of variance-covariance matrices over the three occasions and sphericity were met. Therefore, the univariate approach was used to examine Ftri. Analysis determined that no main effect was present for the dependent variable Ftri.

There was no difference between males and females of the variable Ftri ($F_{1,26} = p > .40$). There was no difference over testing occasion (the repeated measures) ($F_{2,52} < 1$, $p > .50$). Finally, there was no interaction between gender and testing occasions ($F_{2,52} < 1$, $p > .40$) (Appendix S.1).

ATRI (Amplitude Tremor Intensity Index)

Examination of the measure ATRI of the spoken /i/ vowel indicated that neither the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions, nor sphericity was met. Therefore, the multivariate approach tentatively was used to examine ATRI. Analysis determined that the main effect of occasion was present for the dependent variable ATRI.

In pooling over occasions, there was no difference between males and females of the variable ATRI ($F_{1,26} = 2.44$, $p > .10$). There was no interaction between gender and testing occasions ($p < .05$). Wilks' Lambda ($\Lambda = 0.62$, $F_{2,25} = 7.53$, $p < .005$) indicated that there was a significant difference over testing occasion (the repeated measures). The value of eta squared revealed that 38% of the variability pooled over gender was aligned with testing occasion. The power of the test was 0.91 indicating that it was due to more than chance. A significant downward linear trend over the three testing occasions was found ($F_{1,26} = 14.31$, $p < .001$). Also, a significant open upward quadratic trend was found ($F_{1,26} = 7.20$, $p < .01$). Collectively, these trends indicate that ATRI decreased in an asymptotic pattern over time. The linear trend was stronger than the quadratic trend 36% to 22%; the power of the two tests exhibited a similar proportionality, 0.95 to 0.73. Finally, no significant interaction between gender and testing occasion was detected ($\Lambda = 0.89$, $F_{2,25} = 1.51$, $p > .20$).

The univariate approach supports the results of the multivariate approach but with more power. This change in power is owed to the increase in estimates required by the multivariate approach with a small sample size of 28 subjects (Appendix S.2).

Fftr (F_0Tremor Frequency)

Examination of the measure Ftri of the spoken /i/ vowel indicated that the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions was met. However, the assumption of sphericity was not met. Therefore, the multivariate approach was used to examine Fftr. Analysis determined that no main effect was present for the dependent variable Fftr.

There was no difference between males and females of the variable Fftr ($F_{1,26} = 2.34$, $p > .10$), and there was no difference over testing occasion (the repeated measures) ($\Lambda = 0.95$, $F_{2,25} < 1$, $p > .50$). The univariate approach supports the results of the multivariate approach. Finally, there was no interaction between gender and testing occasions ($\Lambda = 0.92$, $F_{2,25} = 1.08$, $p > .30$) (Appendix S.3).

Fatr (Amplitude Tremor Frequency)

Examination of the measure Fatr of the spoken /i/ vowel indicated that both assumptions of homogeneity between males and females of variance-covariance matrices over the three occasions, and sphericity were met. Therefore, the univariate approach was used to examine Fatr. Analysis determined that no main effect was present for the dependent variable Fatr.

There was no difference between males and females of the variable Fatr ($F_{1,26} < 1$, $p > .30$), and there was no difference ($F_{2,52} < 1$, $p > .70$) over testing occasion (the repeated measures). Finally, there was no interaction between gender and testing occasions ($F_{2,52} < 1$, $p > .90$) (Appendix S.4).

Sung Phonation of the /i/ vowel

Fundamental Frequency Measures

F_o (Fundamental Frequency)

Examination of the measure F_O of the sung /i/ vowel indicated that there was homogeneity of variance between males and females at each of the three occasions; however, the variance-covariance matrices over the three occasions exhibited differing occasion to occasion correlations for males and females. However, the assumption of sphericity was met. Therefore, the univariate approach was used to examine F_O. Analysis determined that the main effect of gender was present for the dependent variable F_O.

Males significantly differed from females (males scoring lower) of the variable F_O ($F_{1,26} = 34.12$, $p < .001$). The value of eta squared indicated that 57% of the variability pooled over occasion was aligned with gender. The power of the test was 1.0. There was no difference over testing occasions ($F_{2,52} < 1$, $p > .60$). There was no interaction between gender and testing occasions ($F_{2,52} < 1$, $p > .60$). These results indicate a stable difference between males and females throughout the training (Appendix T.1).

Jita (Absolute Jitter in us)

Examination of the measure Jita of the sung /i/ vowel indicated that both the assumptions of homogeneity between males and females of variance-covariance matrices over the three occasions and sphericity were met. Therefore, the univariate approach was used to examine Jita. Analysis determined that both main effects, that of gender and occasion, as well as the interaction between gender and testing occasion were all present for the dependent variable Jita.

There was a significant difference with males scoring higher than females on the variable Jita ($F_{1,26} = 7.57$, $p < .01$). The value of eta squared indicated

that 22% of the variability pooled over occasion was aligned with gender. The power of the test was 0.75. The most dramatic effect ($F_{2,52} = 37.03$, $p < .001$) was that of testing occasion (the repeated measures). The value of eta squared indicated that 63% of the variability in Jita of spoken /i/, pooled over gender, was aligned with testing occasion (the repeated measures). The power of the test was 1.0. The effect of occasion was stronger than either the interaction or the gender effect by a ratio of nearly 3:1. A significant downward linear trend over the three testings ($F_{1,26} = 44.37$, $p < .001$) and a positive quadratic trend over the three testing occasions ($F_{1,26} = 22.72$, $p < .001$) were found. The downward linear trend indicates that Jita decreased over time. The positive quadratic component reveals that although Jita decreased over time, it bottomed out and slightly increased from occasion two to occasion three. The linear trend is greater in strength than the quadratic component (63% to 47%); each with a power rating of 1.0. These two independent components of trend reflect an dramatic asymptotic training effect over time.

There was a significant interaction between gender and testing occasion ($F_{2,52} = 5.16$, $p < .02$). The value of eta squared indicated that 17% of the variability was aligned with the interaction between gender and occasion. The power of the test was 0.80 (Appendix T.2).

Jitt (Jitter Percent)

Examination of the measure Jitt of the sung /i/ vowel indicated that both assumptions of homogeneity between males and females of variance-covariance matrices over the three occasions, and sphericity were met. Therefore, the univariate approach was used to examine Jitt. Analysis determined that the main effect of occasion was present for the dependent variable Jitt.

There was no difference between males and females of the variable Jitt ($F_{1,26} = 1.94$, $p > .15$). There was a significant difference over testing occasions ($F_{2,52} = 35.71$, $p < .001$). The value of eta squared indicated that 58% of the variability (power rating = 1.0) in Jitt of spoken /i/, pooled over gender, was aligned with testing occasion (the repeated measures). A significant downward linear trend over the three testing occasions ($F_{1,26} = 38.68$, $p < .001$) and a significant positive quadratic trend over the three testing occasions ($F_{1,26} = 28.99$, $p < .001$) were found. The significant downward linear trend indicates that Jitt decreased over time. The positive quadratic component indicates that although Jitt decreased over time, it bottomed out and slightly increased from occasion two to occasion three. Both the linear trend and quadratic trend are very strong (60% to 53% respectively); both tests have a power of 1.0. These two independent components of trend reflect a dramatic decreasing asymptotic training effect over time.

Finally, there was no interaction between gender and testing occasions ($F_{2,52} < 1$, $p > .90$) (Appendix T.3).

RAP (Relative Average Perturbation)

Examination of the measure RAP of the sung/i/ vowel indicated that both of the assumptions of homogeneity between males and females of variance-covariance matrices and sphericity were met. Therefore, the univariate approach was used to examine RAP. Analysis determined that the main effect of occasion was present for the dependent variable RAP.

Males scored significantly lower than females on the variable RAP ($F_{1,26} = 4.06$, $p < .05$). The strength of this effect was 13%, and the power of the test was 0.49. There was a significant difference over testing occasions ($F_{2,52} = 35.41$, $p < .001$). The value of eta squared indicated that 58% of the variability (power

rating = 1.0) in Jitt of sung /i/, pooled over gender, was aligned with testing occasion (the repeated measures). A significant downward linear trend over the three testing occasions ($F_{1,26} = 39.04$, $p < .001$) and a positive quadratic trend over the three testing occasions ($F_{1,26} = 27.40$, $p < .001$) were found. The strengths of the two trends were enormous, (60% - 51% respectively); each with a power rating of 1.0. The significant downward linear trend indicates that RAP decreased over time. The positive quadratic component indicates that although RAP decreased over time, it bottomed out and increased from occasion two to occasion three. These two independent components of trend reflect a dramatic decreasing, asymptotic training effect over time.

Finally, there was no interaction between gender over testing occasions (Appendix T.4).

PPQ (Pitch Perturbation Quotient)

Examination of the measure PPQ of the sung /i/ vowel indicated that the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions was met. However, the assumption of sphericity was not met. Therefore, the univariate approach was used to examine PPQ. Analysis determined that the main effect of occasion was present for the dependent variable PPQ.

There was no difference between males and females of the variable PPQ ($F_{1,26} = 2.33$, $p > .10$). Using the Greenhouse-Geisser adjustment for degrees of freedom, there was a significant difference over testing occasions ($F_{1.59, 41.30} = 39.51$, $p < .001$). The value of eta squared revealed that 60% of the variability (power rating = 1.0) in PPQ of sung /i/, pooled over gender, was aligned with testing occasion (the repeated measures). A significant downward linear trend over the three testing occasions ($F_{1,26} = 42.20$, $p < .001$) and a positive quadratic

trend over the three testing occasions ($F_{1,26} = 33.07$, $p < .001$) were found. The linear trend exceeded by a tenth the strength of the quadratic trend (61% - 55%). The two tests were nearly equivalent in power (1.0 and 0.99 respectively). The significant downward linear trend indicates that PPQ decreased over time. The positive quadratic component indicates that although PPQ decreased over time, it bottomed out and slightly increased from occasion two to occasion three. These two independent components of trend reflect a dramatic decreasing, asymptotic training effect over time.

Finally, the nature of the interaction effect is ordinal with a diminishing difference, favoring females in excess of males, over the testing occasions (Appendix T.5).

sPPQ (Smoothed Pitch Perturbation Quotient)

Examination of the measure sPPQ of the sung /i/ vowel indicated that the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions was met; however, the sphericity assumption was not met. Therefore, the multivariate approach was used to examine sPPQ. Analysis determined that both main effects, that of gender and occasion, were present for the dependent variable sPPQ.

Males scored higher than did females on the variable sPPQ ($F_{1,26} = 6.47$, $p < .02$). The value of eta squared indicated that 20% of the variability (power rating = .69) in sPPQ of sung /i/, pooled over occasions, was aligned with gender. Wilks' Lambda ($\Lambda = 0.29$, $F_{2,25} = 31.20$, $p < .001$) indicated that there was a significant difference over testing occasion (the repeated measures). The value of eta squared indicated that 71% of the variability pooled over gender was aligned with testing occasion (the repeated measures). The power of the test was 1.0. The occasions main effect was stronger by a ratio of more than 3:1 to that of gender.

The power of the respective tests was also much stronger (1.0 vs. .69). A significant downward linear trend over the three testing occasions ($F_{1,26}$ = 19.53, $p < .001$) and a positive quadratic trend over the three testing occasions ($F_{1,26}$ = 42.84, $p < .001$) were found. The quadratic trend was stronger than the linear trend (62% vs. 43%); the two trend tests had nearly equivalent powers (0.99). The significant downward linear trend indicates that sPPQ decreased over time. The positive quadratic component indicates that although sPPQ decreased over time, it bottomed out and slightly increased from occasion two to occasion three. These two independent components of trend reflect a dramatic decreasing, asymptotic training effect over time.

Finally, there was no interaction between gender and testing occasions (Λ = 0.97, $F_{2,25} < 1$, $p > .60$) (Appendix T.6).

vFo (Fundamental Frequency Variation)

Examination of the measure vFo of the sung /i/ vowel indicated that the variances were homogeneous between males and females on each of the three occasions; however the occasion to occasion correlation differed between males and females. The sphericity assumption was not met. Therefore, the multivariate approach was used to examine vFo. Analysis determined that the main effect of occasion was present for the dependent variable vFo.

There was no difference between males and females of the variable vFo ($F_{1,26} < 1$, $p > .40$). Wilks' Lambda (Λ = 0.26, $F_{2,25}$ = 36.40, $p < .001$) indicated that there was a significant difference over testing occasion. The value of eta squared revealed that 75% of the variability pooled over gender was aligned with testing occasion (the repeated measures). The power of the test was 1.0. A significant downward linear trend over the three testing occasions ($F_{1,26}$ = 28.55, $p < .001$), and a positive quadratic trend over the three testing occasions ($F_{1,26}$ =

56.81, $p < .001$) were found. The quadratic component was stronger than the linear trend (69% vs. 52%); each with a power rating of 1.0. The significant downward linear trend indicates that sPPQ decreased over time, and the positive quadratic trend indicates that although sPPQ decreased over time, it bottomed out and slightly increased from occasion two to occasion three. These two independent components of trend reflect a dramatic decreasing, asymptotic training effect over time. Finally, there was no interaction between gender and testing occasions ($\Lambda = 0.91$, $F_{2,25} = 1.19$, $p > .30$).

The results of the univariate approach support the results of the multivariate approach but with more power. This change in power is the result of the increase in estimates required by the multivariate approach with a small sample size of 28 subjects (Appendix T.7).

Amplitude Measures

ShdB (Shimmer in decibels)

Examination of the measure ShdB of the sung /i/ vowel indicated that the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions was met. However, the assumption of sphericity was not met. Therefore, the multivariate approach was used to examine ShdB. Analysis determined that the main effect of occasion was present for the dependent variable ShdB.

There was no difference between males and females of the variable ShdB ($F_{1,26} = 3.63$, $p > .05$). Wilks' Lambda ($\Lambda = 0.36$, $F_{2,25} = 22.06$, $p < .001$) indicated that there was a significant difference over testing occasion (the repeated measures). The value of eta squared revealed that 64% of the variability (power rating = 1.0) in ShdB of sung /i/, pooled over gender, was aligned with testing occasion. A significant downward linear trend over the three testing

occasions ($F_{1,26} = 45.17$, $p < .001$) and a positive quadratic trend over the three testing occasions ($F_{1,26} = 23.30$, $p < .001$) were found. The linear trend was stronger than the quadratic trend (63% vs. 47%); the power of each test was 1.0. The significant downward linear trend indicates that ShdB decreased over time. The positive quadratic component indicates that although ShdB decreased over time, it bottomed out and slightly increased from occasion two to occasion three. These two independent components of trend reflect a dramatic decreasing, asymptotic training effect over time.

Finally, there was no interaction between gender and testing occasions ($\Lambda = 0.99$, $F_{2,25} = 0.11$, $p > .80$) (Appendix U.1).

Shim (Shimmer Percent)

Examination of the measure Shim of the sung /i/ vowel indicated that the variance between males and females were homogeneous on each occasion; however, the occasion-to-occasion correlations differed for males and females. Additionally, the assumption of sphericity was not met. Therefore, the multivariate approach was used to examine Shim. Analysis determined that both main effects, that of gender and occasion, were present for the dependent variable Shim.

Males scored significantly higher than females on the variable Shim ($F_{1,26} = 5.30$, $p < .05$). The value of eta squared indicated that 17% of the variability pooled over occasions was aligned with gender. The power of the test was 0.60. Wilks' Lambda ($\Lambda = 0.30$, $F_{2,25} = 28.65$, $p < .001$) indicated that there was a significant difference over testing occasion (the repeated measures). The value of eta squared revealed that 70% of the variability pooled over gender was aligned with testing occasion. The power of the test was 1.0. The testing was four times the strength of the gender effect. A significant downward linear trend over the

three testing occasions ($F_{1,26} = 58.14$, $p < .001$, and a significant positive quadratic trend over the three testing occasions ($F_{1,26} = 23.82$, $p < .001$) were found. The linear trend was stronger than the quadratic trend (70% vs. 48%); the power of each test was 1.0. The significant downward linear trend indicates that Shim decreased over time. The positive quadratic component indicates that although Shim decreased over time, it bottomed out and slightly increased from occasion two to occasion three. These two independent components of trend reflect a dramatic decreasing, asymptotic training effect over time.

Finally, there was no interaction between gender and testing occasions ($\Lambda = 0.30$, $F_{2,25} = 28.65$, $p < .05$) (Appendix U.2).

APQ (Amplitude Perturbation Quotient)

Examination of the measure APQ of the sung /i/ vowel indicated that the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions was met; however the sphericity assumption was not met. Therefore, the multivariate approach was used to examine APQ. Analysis determined that both main effects, that of gender and occasion, were present for the dependent variable APQ.

Males scored significantly higher than females on the variable APQ ($F_{1,26} = 6.51$, $p < .02$). The value of eta squared revealed that 20% of the variability pooled over occasion was aligned with gender. The power of the test was 0.69. Wilks' Lambda ($\Lambda = 0.32$, $F_{2,25} = 26.52$, $p < .001$) indicated that there was a significant difference over testing occasion (the repeated measures). The value of eta squared revealed that 68% of the variability in APQ of sung /i/, pooled over gender, was aligned with testing occasion. The occasion effect was three times stronger than the gender effect; the power of the test was superior (1.0 vs. 0.69). A significant downward linear trend over the three testing occasions ($F_{1,26} =$

42.76, $p < .001$) and a significant positive quadratic trend over the three testing occasions ($F_{1,26} = 45.59$, $p < .001$) were found. The two traits were basically equivalent in strength (62% vs. 64%) and in power corresponding to the testing (1.0). The significant downward linear trend indicates that APQ decreased over time. The positive quadratic component indicates that although APQ decreased over time, it bottomed out and slightly increased from occasion two to occasion three. These two independent components of trend reflect a dramatic training effect over time.

Finally, there was no interaction between gender and testing occasions ($\Lambda = 0.96$, $F_{2,25} < 1$, $p > .50$) (Appendix U.3).

sAPQ (Smoothed Amplitude Perturbation Quotient)

Examination of the measure sAPQ of the sung/i/ vowel indicated that neither the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions, nor the assumption of sphericity was met. Therefore, the multivariate approach was used to examine sAPQ. Analysis determined that the main effect of occasion was present for the dependent variable sAPQ.

There was no difference between males and females of the variable sAPQ ($F_{1,26} < 1$, $p > .90$). Wilks' Lambda ($\Lambda = 0.44$, $F_{2,25} = 15.96$, $p < .001$) indicated that there was a significant difference over testing occasion (the repeated measures). The value of eta squared revealed that 56% of the variability in sAPQ of sung /i/, pooled over gender, was aligned with testing occasion. The power of the test was 1.0. A significant downward linear trend over the three testing occasions ($F_{1,26} = 15.94$, $p < .001$) and a positive quadratic trend over the three testing occasions ($F_{1,26} = 24.38$, $p < .001$) were found. The positive quadratic trend was 10% stronger than the downward linear trend (48% vs. 38%); the power

of each test was 1.0. The significant downward linear trend indicates that sAPQ decreased over time. The positive quadratic trend indicates that although sAPQ decreased over time, it bottomed out and slightly increased from occasion two to occasion three. These two independent components of trend reflect a dramatic decreasing, asymptotic training effect over time. Finally, there was no interaction between gender and testing occasions ($\Lambda = 0.91$, $F_{2,25} = 1.19$, $p > .30$).

The univariate approach supports the results of the multivariate approach, especially when both approaches are tenuous, given the assumption violations (Appendix U.4).

vAm (Peak-Amplitude Variation)

Examination of the measure vAm of the sung /i/ vowel indicated that neither the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions, nor the assumption of sphericity was met. Therefore, the multivariate approach was used to examine vAm. Analysis determined that both main effects, that of gender and occasion, were present for the dependent variable vAm.

Males tended to score higher than the females on the variable sAPQ ($F_{1,26} = 6.72$, $p < .02$). The value of eta squared indicated that 20% of the variability in vAm of sung /i/, pooled over occasions, was aligned with gender. The power of the test was 0.70. Wilks' Lambda ($\Lambda = 0.54$, $F_{2,25} = 10.46$, $p < .001$) indicated that there was a significant difference over testing occasion (the repeated measures). The value of eta squared revealed that 46% of the variability in vAm of sung /i/, pooled over gender, was aligned with testing occasion. The effect was more than twice as strong as the gender effect. A significant downward linear trend over the three testing occasions ($F_{1,26} = 17.45$, $p < .001$) and a positive quadratic trend over the three testing occasions ($F_{1,26} = 14.26$, $p < .001$) were

found. The two trends were within 5% strength of each other. The power of each test was 1.0. The significant downward linear trend indicates that vAm decreased over time. The positive quadratic component indicates that although vAm decreased over time, it bottomed out and slightly increased from occasion two to occasion three. These two independent components of trend reflect a dramatic training effect over time. Finally, there was no interaction between gender and testing occasions ($\Lambda = 0.85, F_{2,25} = 2.21, p > .10$).

The univariate approach supports the results of the multivariate approach (Appendix U.5).

Noise Related Measures

NHR (Noise to Harmonic Ratio)

Examination of the measure NHR of the sung /i/ vowel indicated that neither the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions, nor the assumption of sphericity was met. Therefore, the multivariate approach was used to examine NHR. Analysis determined that the main effect of gender was present for the dependent variable NHR.

Males scored significantly higher than females on the variable NHR ($F_{1,26} = 10.18, p < .005$). The value of eta squared indicated that 28% of the variability of NHR in sung /i/, pooled over occasions, was aligned with gender. The power of the test was 0.86. There was no difference over testing occasions ($\Lambda = 0.85, F_{2,25} = 2.29, p > .10$). There was a significant interaction between gender and testing occasions ($\Lambda = 0.78, F_{2,25} = 3.36, p < .05$). The strength of this effect was 21% (eta squared) with power of the test 0.58. This result was corroborated the Greenhouse-Geisser adjusted univariate approach ($F_{1.42, 36.92} = 5.50, p < .02$).

The nature of this interaction was a progressively widening difference over occasions, males exceeding females (Appendix V.1).

VTI (Voice Turbulence Index)

Examination of the measure VTI of the sung /i/ vowel indicated that the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions was not met; however, the assumption of sphericity was met. Therefore, the univariate approach was used to examine VTI. Analysis determined that the main effect of gender was present for the dependent variable VTI.

Males significantly exceeded females on the variable VTI ($F_{1,26} = 10.82$, $p < .01$). The value of eta squared indicated that 29% of the variability of VTI in sung /i/, pooled over occasion, was aligned with gender. The power of the test was 0.88. There was no difference over testing occasions ($F_{2,52} = 1.36$, $p > .20$). Finally, there was no interaction between gender and testing occasions ($F_{2,52} = 1.98$, $p > .20$) (Appendix V.2).

SPI (Soft Phonation Index)

Examination of the measure SPI of the sung /i/ vowel indicated that the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions was not met; however, the assumption of sphericity was met. Therefore, the univariate approach was used to examine SPI. Analysis determined that both main effects, that of gender and occasion, were present for the dependent variable SPI.

Females significantly exceeded males on the variable VTI ($F_{1,26} = 5.66$, $p < .03$). The value of eta squared indicated that 18% of the variability of SPI in sung /i/, pooled over occasion, was aligned with gender. The power of the test was

only 0.63. The testing occasion effect was significant ($F_{2,52} = 12.61$, $p < .001$) and has twice the strength of effect as gender. The value of eta squared indicated that 33% of the variability of SPI in sung /i/, pooled over gender, was aligned with testing occasion (the repeated measures). The power of the test was 1.0. There was no interaction between gender and testing occasions ($F_{2,52} = 1.03$, $p > .90$). Both a significant downward linear trend ($F_{1,26} = 17.58$, $p < .001$) and a significant positive quadratic trend ($F_{1,26} = 8.24$, $p < .01$) were detected. The strength of the linear trend (40%) was almost twice that of the quadratic trend (24%). This combination of trends indicated a downward decreasing, asymptotic trend over the training program (Appendix V.3).

Tremor Related Measures

Ftri (F_o Tremor Intensity Index)

Examination of the measure Ftri of the sung /i/ vowel indicated that the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions was met. However, the assumption of sphericity was not met. Therefore, the multivariate approach was used to examine Ftri. Analysis determined that the main effect of occasion was present for the dependent variable Ftri.

There was no difference between males and females of the variable Ftri ($F_{1,26} = 2.47$, $p > .10$). Wilks' Lambda ($\Lambda = 0.64$, $F_{2,25} = 7.01$, $p < .005$) indicated that there was a significant difference over testing occasion (the repeated measures). The value of eta squared revealed that 39% of the variability in Ftri of sung /i/, pooled over gender, was aligned with testing occasion. The power of the test was 0.89. Finally, there was no interaction between gender and testing occasions ($\Lambda = 0.96$, $F_{2,25} < 1$, $p > .60$) (Appendix W.1).

ATRI (Amplitude Tremor Intensity Index)

Examination of the measure ATRI of the sung /i/ vowel indicated that neither the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions, nor the assumption of sphericity was met. Therefore, the multivariate approach was used to examine ATRI. Analysis determined that the main effect of occasion was present for the dependent variable ATRI.

Females scored significantly higher than males on the variable ATRI ($F_{1,26} = 4.03$, $p < .05$). The strength of the effect was 13% (eta squared); the power of the test was only 0.49. Wilks' Lambda ($\Lambda = 0.55$, $F_{2,25} = 10.24$, $p < .001$) indicated that there was a significant difference over testing occasion (the repeated measures). The value of eta squared revealed that 45% of the variability of ATRI in sung /i/, pooled over gender, was aligned with testing occasion. The power of the test was 0.97. Overall, the occasion effect was more than three times the strength of the gender effect. A significant downward linear trend over the three testing occasions ($F_{1,26} = 17.25$, $p < .001$) was found. Additionally, a significant positive quadratic trend ($F_{1,26} = 11.71$, $p < .005$) was detected. The strengths of the two trends were 40% to 31% respectively. The power of both tests is in excess of 0.91. The combination of the downward linear trend and the positive quadratic trend indicates an ATRI decreasing asymptotic pattern over the training program. Finally, there was no interaction between gender and testing occasions ($\Lambda = 0.90$, $F_{2,25} = 1.44$, $p > .25$)

The univariate approach supports the results of the multivariate approach, especially in light of the tenuous assumptions (Appendix W.2).

Fftr (F_0 Tremor Frequency)

Examination of the measure Fftr of the sung/i/ vowel indicated that there was homogeneity of variance between males and females at each of the three occasions; however, the variance-covariance matrices over the three occasions exhibited differing occasions to occasion correlations for males and females. However, the sphericity assumption was not met. Therefore, the multivariate approach was used to examine Fftr. Analysis determined that the main effect of occasion was present for the dependent variable Fftr.

There was no difference between males and females of the variable Fftr ($F_{1,26} = 2.28$, $p > .10$). Wilks' Lambda ($\Lambda = 0.63$, $F_{2,25} = 7.28$, $p < .005$). indicated that there was a significant difference over testing occasion (the repeated measures). The value of eta squared revealed that 36% of the variability pooled over gender was aligned with testing occasion. The power of the test was 0.91. The univariate approach supports the results of the multivariate approach. Finally, there was no interaction between gender and testing occasions ($\Lambda = 0.85$, $F_{2,25} = 2.19$, $p > .10$) (Appendix W.3).

Fatr (Amplitude Tremor Frequency)

Examination of the measure Fatr of the sung /i/ vowel indicated that both the assumption of homogeneity between males and females of variance-covariance matrices over the three occasions and the assumption of sphericity were met. Therefore, the univariate approach was used to examine Fatr. Analysis determined that the main effect of occasion was present for the dependent variable Fatr.

There was no difference between males and females of the variable Fatr ($F_{1,26} = 1.38$, $p > .20$), but there was a significant difference over testing occasion (the repeated measures) ($F_{2,52} = 5.27$, $p < .01$). The value of eta squared

indicated that 17% of the variability of Fatr in sung /i/, pooled over gender, was aligned with occasion. The power of the test was 0.81. Only a significant downward linear trend ($F_{1,26} = 8.56$, $p < .01$) was detected. Finally, there was no interaction between gender and testing occasions ($F_{2,52} = 1.46$, $p > .20$) (Appendix W.4).

Spoken Phonation of the /u/ vowel

Fundamental Frequency Measures

F_o (Fundamental Frequency)

Examination of the measure F_O of the spoken /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was not met; however, the sphericity assumption was met. Therefore, both the univariate and multivariate approaches were used to examine F_O. The analyses determined that both main effects for gender and occasion were present for the dependent variable F_O.

Females scored significantly higher than males on the variable F_O ($F_{1,26} = 95.55$, $p < .001$). The value of eta squared indicated that 78% of the variability pooled over occasions was aligned with gender. There was a significant difference over occasions ($F_{2,52} = 3.40$, $p < .05$). This result was not corroborated with the less powerful multivariate test ($\Lambda = 0.79$, $F_{2,25} = 3.16$, $p > .05$). The value of eta squared indicated that 11% of the variability of F_O was aligned with testing occasion. The proportion of variance of F_O of spoken /u/, aligned with testing occasion, was 11% while the power of this test was 0.61. The strength of variability for the gender and occasion effects indicates that the stronger effect is gender; the power of the respective tests was 1.0 Vs 0.61. From the tests of independent trend components, only a significant quadratic trend ($F_{1,26} = 5.01$,

$p < .05$) was found. This suggests a slight U-Shaped pattern of the combined means over the three occasions.

Finally, there was there was no interaction between gender and occasion detected with the univariate approach ($F_{2,52} = 1.24$, $p > .25$) (Appendix X.1).

Jita (Absolute Jitter in us)

Examination of the measure Jita of the spoken /u/ vowel indicated that both the assumptions of homogeneity of variance-covariance matrices of the three occasions between males and females and that of sphericity were met. Therefore, the univariate approach was used to examine Jita. The analysis determined that a main effect for occasion was present for the dependent variable Jita.

Males and females were indistinguishable on the variable Jita ($F_{1,26} < 1$, $p > .50$). There was a significant difference over occasion ($F_{2,25} = 21.58$, $p < .001$). The value of eta squared indicated that 40% of the variability of Jita was aligned with testing occasion. The power of this test was maximized (1.0). From the tests of independent trend components, a significant downward linear trend ($F_{1,26} = 31.95$, $p < .001$) over the three testing occasions was found. This implies a residual or practice effect over the training program.

Finally, there was there was no interaction between gender and occasion detected with the univariate approach ($F_{2,52} = 1.20$, $p > .30$) (Appendix X.2).

Jitt (Jitter Percent)

Examination of the measure Jitt of the spoken /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was not met; however, the sphericity assumption was met. Therefore, both the univariate and multivariate approaches were used to

examine Jitt. The analyses determined that both main effects for gender and occasion were present for the dependent variable Jitt.

Females scored significantly higher than males on the variable Jitt ($F_{1,26}$ = 20.43, p< .001). The value of eta squared indicated that 44% of the variability of Jitt was aligned with gender. Wilks' Lambda (Λ = 0.29, $F_{2,25}$ = 29.27, p< .001)indicated that there were a significant difference over occasion. The value of eta squared indicated that 70% of the variability in Jitt of spoken /u/, pooled over gender, was aligned with testing occasion ($F_{2,25}$ = 21.58, p < .001). The power of this test was 1.0 or at its maximum strength. The ratio of the strengths of the two main effects was nearly 2:1 indicating that the occasion effect was the more dramatic; however, the powers of the two tests are almost equal. From the tests of independent trend components, a significant downward linear trend ($F_{1,26}$ = 42.61, p < .001) over the three testing occasions was found.

The results of the univariate approach ($F_{2,52}$ = 23.64, p < .001) corroborate the results of the multivariate approach. Finally, there was there was no interaction between gender and occasion detected with either the univariate test ($F_{2,52}$ = 2.75, p > .07) or multivariate test (Λ = 0.82, $F_{2,25}$ = 2.66, p > .08) (Appendix X.3).

RAP (Relative Average Perturbation)

Examination of the measure RAP of the spoken /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was not met; however, the sphericity assumption was met. Therefore, both the univariate and multivariate approaches were used to examine RAP. The analyses determined that both main effects for gender and occasion were present for the dependent variable RAP.

Females scored significantly higher than males on the variable RAP ($F_{1,26}$ = 20.41, p< .001). The value of eta squared indicated that 44% of the variability of RAP was aligned with gender. Wilks' Lambda (Λ = 0.29) indicated that there were a significant difference over occasion ($F_{2,25}$ = 21.58, p < .001). The value of eta squared indicated that 70% of the variability in RAP of spoken /u/, pooled over gender, was aligned with testing occasion. The power of this test was at its maximum, 1.0. The ratio of strength of the two main effects, nearly 2:1, indicates that occasion is the more dramatic effect; however the powers of the two tests are almost equal (1.0 and .99 respectively). From the tests of independent trend components, both a significant downward linear trend ($F_{1,26}$ = 43.02, p < .001) over the three testing occasions and a significant positive quadratic trend ($F_{1,26}$ = 7.47, p < .01) were found. The pattern of these components of trend suggest that females on average consistently scored 0.30 above the average of the males, finally doubling the male average on the last measurement occasion

The results of the univariate test ($F_{2,52}$ = 23.38, p < .001) corroborate the results of the multivariate test. Finally, there was there was no interaction between gender and occasion detected with either the univariate test ($F_{2,52}$ = 2.86, p > .06) or multivariate test (Λ = 0.81, $F_{2,25}$ = 2.75, p > .08) (Appendix X.4).

PPQ (Pitch Perturbation Quotient)

Examination of the measure PPQ of the spoken /u/ vowel indicated that both the assumptions of homogeneity of variance-covariance matrices of the three occasions between males and females and sphericity assumption were met. Therefore, the univariate approach was used to examine PPQ. The analysis determined that both main effects for gender and occasion were present for the dependent variable PPQ.

Females scored significantly higher than males on the variable PPQ ($F_{1,26}$ = 24.22, p< .001). The value of eta squared indicated that 48% of the variability of PPQ was aligned with gender. There were a significant difference over occasion ($F_{2,52}$ = 25.47, p < .001). The value of eta squared indicated that 49% of the variability in PPQ of spoken /u/, pooled over gender, was aligned with testing occasion. The power of this test was 1.0 or maximized. Both effects, that of gender and occasion, are basically equal in strength and the powers of the two tests were nearly equivalent (1.0 and .997 respectively). From the tests of independent trend components, both a significant downward linear trend ($F_{1,26}$ = 42.67, p < .001) over the three testing occasions and a significant positive quadratic trend ($F_{1,26}$ = 9.66, p < .01) were found.

Finally, there was there was no interaction between gender and occasion detected with the univariate test ($F_{2,52}$ = 2.60, p > .08) (Appendix X.5).

sPPQ (Smoothed Pitch Perturbation Quotient)

Examination of the measure sPPQ of the spoken /u/ vowel indicated that both of the assumptions of homogeneity of variance-covariance matrices of the three occasions between males and females and sphericity were met. Therefore, the univariate approach was used to examine sPPQ. The analysis determined that both main effects for gender and occasion were present for the dependent variable sPPQ.

Females scored significantly higher than males on the variable sPPQ ($F_{1,26}$ = 6.07, p< .025). The value of eta squared indicated that 18% of the variability of PPQ was aligned with gender. There was a significant difference over testing occasion (repeated measures) ($F_{2,52}$ = 20.67, p < .001). The value of eta squared indicated that 44% of the variability in sPPQ of spoken /u/, pooled over gender, was aligned with testing occasion. The power of this test was at maximum

strength (1.0). The effect for occasion was stronger than that for gender by a ratio of more than 2:1, and the tests were more powerful as well (1.0 Vs .65 respectively). From the tests of independent trend components, both a significant downward linear trend ($F_{1,26} = 31.11$, $p < .001$) over the three testing occasions and a significant positive quadratic trend ($F_{1,26} = 8.85$, $p < .01$) were found. The combination of these two trends implies a decreasing asymptotic pattern over the program.

Finally, there was there was no interaction between gender and occasion detected with the univariate test ($F_{2,52} = 2.21$, $p > .10$) (Appendix X.6).

vFo (Fundamental Frequency Variation)

Examination of the measure vFo of the spoken /u/ vowel indicated that both the assumptions of homogeneity of variance-covariance matrices of the three occasions between males and females and sphericity were met. Therefore, the univariate approach was used to examine vFo. The analysis determined that the main effect of occasion was present for the dependent variable vFo.

The males and females were indistinguishable on the variable vFo ($F_{1,26} = 2.12$, $p > .20$). There were a significant difference over testing occasion (repeated measures) ($F_{2,52} = 17.00$, $p < .001$). The value of eta squared indicated that 39% of the variability in vFo of spoken /u/, pooled over gender, was aligned with testing occasion. The power of this test was 1.0 or maximized. From the tests of independent trend components, both a significant downward linear trend ($F_{1,26} = 27.02$, $p < .001$) over the three testing occasions and a significant positive quadratic trend ($F_{1,26} = 7.21$, $p < .01$) were found. The combination of these two trend components suggests a decreasing asymptotic pattern on the average for vFo training program.

Finally, there was there was no interaction between gender and occasion detected with the univariate ($F_{2,52} = 0.88$, $p > .40$) approach (Appendix X.7).

Amplitude Measures

ShdB (Shimmer in decibels)

Examination of the measure ShdB of the spoken /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was not met. However, the sphericity assumption was met. Therefore, both the univariate and multivariate approaches were used to examine ShdB. Analysis determined that the main effect of occasion was present for the dependent variable ShdB.

There was no difference between males and females of the variable ShdB ($F_{1,26} = .22$, $p > .60$). Wilks' Lambda ($\Lambda = 0.67$)indicated that there was a significant difference over occasion ($F_{2,25} = 6.14$, $p < .01$). The value of eta squared indicated that 33% of the variability in ShdB of spoken /u/, pooled over genders, was aligned with testing occasion. The power of this test was 0.85 which indicates that the alignment is due to more than chance. From the independent trend components both significant linear trend ($F_{1,26} = 9.20$, $p < .01$) and quadratic trend ($F_{1,26} = 7.91$, $p < .01$)over the three testing occasions were found. These components indicated a general downward asymptotic pattern exhibited by both males and females.

The results of the univariate approach ($F_{2,52} = 8.75$, $p < .001$) support the results of the multivariate approach but with more power (0.96). Finally, there was there was no interaction between gender and occasion detected with either the univariate ($F_{2,52} = 2.08$, $p > .10$) or multivariate approach ($\Lambda = 0.87$, $F_{2,25} = 1.81$, $p > .15$) (Appendix Y.1).

Shim (Shimmer Percent)

Examination of the measure Shim of the spoken /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was not met. However, the sphericity assumption was met. Therefore, both the univariate and multivariate approaches were used to examine Shim. Analyses determined that the main effect of occasion was present for the dependent variable ShdB.

There was no difference between males and females of the variable Shim ($F_{1,26} < 1$, $p > .50$). Wilks' Lambda ($\Lambda = 0.66$)indicated that there was a significant difference over occasion ($F_{2,25} = 6.30$, $p < .01$). The value of eta squared indicated that 33% of the variability in Shim of spoken /u/, pooled over genders, was aligned with testing occasion. The power of this test was 0.86 which indicates that the alignment is due to more than chance. From the independent trend components, both significant linear trend ($F_{1,26} = 9.24$, $p < .01$) and quadratic trend ($F_{1,26} = 7.63$, $p < .01$) over the three testing occasions were found. The nature of this combined trend was a downward asymptotic pattern over the 8 months of the program.

The results of the univariate approach ($F_{1,26} = 8.66$, $p < .001$) support the results of the multivariate approach but with more power (0.96). Finally, there was there was no interaction between gender and occasion detected with either the univariate ($F_{2,52} = 1.88$, $p > .15$) or multivariate approach ($\Lambda = 0.88$, $F_{2,25} = 1.66$, $p > .20$) (Appendix Y.2).

APQ (Amplitude Perturbation Quotient)

Examination of the measure APQ of the spoken /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was not met; and the sphericity assumption

was not met. Therefore, the multivariate approach was used to examine APQ. Analysis determined that the main effect of occasion was present for the dependent variable APQ.

There was no difference between males and females of the variable APQ ($F_{1,26} = 3.66$, $p > .05$). Wilks' Lambda ($\Lambda = 0.60$) indicated that there was a significant difference over occasion ($F_{2,25} = 8.09$, $p < .01$). The value of eta squared indicated that 39% of the variability in APQ of spoken /u/, pooled over genders, was aligned with testing occasion. The power of this test was 0.93 which indicates that the alignment is due to more than chance. From the independent trend components both significant linear trend ($F_{1,26} = 11.20$, $p < .01$) and quadratic trend ($F_{1,26} = 11.53$, $p < .01$) over the three testing occasions were found. The combined trends indicate a downward asymptotic trend over the duration of the training program.

Finally, no interaction between gender and occasion was detected with the multivariate approach ($\Lambda = 0.93$, $F_{2,25} < 1$, $p > .55$) (Appendix Y.3).

sAPQ (Smoothed Amplitude Perturbation Quotient)

Examination of the measure sAPQ of the spoken /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was not met; and the sphericity assumption was not met. Therefore, the multivariate approach was used to examine sAPQ. Analysis determined that the main effect of occasion was present for the dependent variable sAPQ.

There was no difference between males and females of the variable sAPQ ($F_{1,26} < 1$, $p > .40$). Wilks' Lambda ($\Lambda = 0.74$) indicated that there was a significant difference over occasion ($F_{2,25} = 4.33$, $p < .05$). The value of eta squared indicated that 25% of the variability in sAPQ of spoken /u/, pooled over

genders, was aligned with testing occasion. The power of this test was 0.70 which indicates that the alignment is due to slightly more than chance. From the independent trend components both significant linear trend ($F_{1,26} = 7.31$, $p < .02$) and quadratic trend ($F_{1,26} = 8.77$, $p < .01$) over the three testing occasions were found. Both males and females exhibited a downward asymptotic pattern over the training program.

Finally, no interaction between gender and occasion was detected with the multivariate approach ($\Lambda = 0.93$, $F_{2,25} < 1$, $p > .40$) (Appendix Y.4).

vAm (Peak-Amplitude Variation)

Examination of the measure vAm of the spoken /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was not met; and the sphericity assumption was not met. Therefore, the multivariate approach was used to examine vAm. Analysis determined that the main effect of occasion was present for the dependent variable vAm.

There was no difference between males and females of the variable vAm ($F_{1,26} = 2.73$, $p > .10$). Wilks' Lambda ($\Lambda = 0.66$) indicated that there was a significant difference over occasion ($F_{2,25} = 6.35$, $p < .01$). The value of eta squared indicated that 33% of the variability in vAm of spoken /u/, pooled over genders, was aligned with testing occasion. The power of this test was 0.86 which indicates that the alignment is due to more than chance. From the independent trend components, both significant linear trend ($F_{1,26} = 10.59$, $p < .01$) and quadratic trend ($F_{1,26} = 9.18$, $p < .01$) over the three testing occasions were found. Males and females exhibited a J-shaped pattern, decreasing over time.

Finally, no interaction between gender and occasion was detected with the multivariate approach ($\Lambda = 0.93$, $F_{2,25} < 1$, $p > .40$) (Appendix Y.5).

Noise Related Measures

NHR (Noise to Harmonic Ratio)

Examination of the measure NHR of the spoken /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was met; and the sphericity assumption was met. Therefore, the univariate approach was used to examine NHR. Analysis determined that both main effects for gender and occasion were present for the dependent variable NHR.

Males exhibited a significantly higher mean across occasions on the variable NHR than did females ($F_{1,26} = 8.56$, $p < .01$). The value of eta squared indicated that 24% of the variability in NHR of spoken /u/ was aligned with gender. Pooling over genders, there was a significant difference over occasion ($F_{2,52} = 8.71$, $p < .01$). The value of eta squared indicated that 25% of the variability in NHR of spoken /u/, pooled over genders, was aligned with testing occasion. Both of the effects are approximately equal in strength; however, the effect of testing occasion has a stronger power ratio (.96 vs. .80) than that of the gender effect. From the independent trend components, only a significant upward linear trend ($F_{1,26} = 14.70$, $p < .001$) over the three testing occasions was found. This indicates that NHR increased over the testing occasions (repeated measures). This independent component of trend reflects a dramatic training effect over time.

Finally, there was there was no interaction between gender and occasion detected with the multivariate approach ($F_{2,52} = 2.27$, $p > .10$) (Appendix Z.1).

VTI (Voice Turbulence Index)

Examination of the measure VTI of the spoken /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions

between males and females was not met. However, the sphericity assumption was met. Therefore, both the univariate and multivariate approaches were used to examine VTI. Analysis determined that the main effect of occasion was present for the dependent variable VTI.

There was no difference between males and females of the variable VTI ($F_{1,26} = 3.51$, $p > .05$). Wilks' Lambda ($\Lambda = 0.61$) indicated that there was a significant difference over occasion ($F_{2,25} = 7.69$, $p < .01$). The value of eta squared indicated that 38% of the variability in VTI of spoken /u/, pooled over genders, was aligned with testing occasion. The power of the test was 0.92 which indicated that the alignment was due to more than chance. From the independent trend components, only a significant upward linear trend ($F_{1,26} = 14.35$, $p < .001$) over the three testing occasions was found. This indicates that VTI increased over the testing occasions (repeated measures). This independent component of trend reflects a dramatic training effect over time.

The univariate approach support the results of the multivariate approach. Finally, there was there was no interaction between gender and occasion detected with the multivariate ($\Lambda = 0.95$, $F_{2,25} < 1$, $p > .50$) or univariate ($F_{2,52} = < 1$, $p > .50$) approaches (Appendix Z.2).

SPI (Soft Phonation Index)

Examination of the measure SPI of the spoken /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices over the three occasions between males and females and the sphericity assumption were met. Therefore, the univariate approach was used to examine SPI. Analysis determined that both main effects for gender and occasion were present for the dependent variable SPI.

The average over three occasions was significantly higher for females than males on the variable SPI ($F_{1,26} = 4.90$, $p < .05$). The value of eta squared indicated that 15% of the variability in SPI of spoken /u/ was aligned with gender. There was a significant difference over occasion (repeated measures) ($F_{2,52} = 19.11$, $p < .001$). The value of eta squared indicated that 42% of the variability in SPI of spoken /u/, pooled over genders, was aligned with testing occasion. The power of the test was at maximum strength; 1.0. The effect of testing occasion was stronger than the effect of gender by a ratio of nearly 3:1. Also, the power of gender was 0.56 which indicated that the alignment was most likely due to chance. From the independent trend components, a significant downward linear trend over the three testing occasions was found. This indicates that SPI decreased over the testing occasions (repeated measures). This independent component of trend reflects a dramatic training effect over time.

Finally, there was there was no interaction between gender and occasion detected with the univariate ($F_{2,52} = 0.44$, $p > .60$) approach (Appendix Z.3).

Tremor Related Measures

Ftri (F_0 Tremor Intensity Index)

Examination of the measure Ftri of the spoken /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was not met; however, the sphericity assumption was met. Therefore, the multivariate approach was used to examine Ftri. The analysis determined that no main or interaction effects were present for the dependent variable Ftri.

There was no difference between males and females of the variable Ftri ($F_{1,26} = 1.79$, $p > .15$). There was no difference ($\Lambda = 0.88$, $F_{2,25} = 1.62$, $p > .20$) over testing occasion (repeated measures). Finally, there was there was no

interaction between gender and occasion detected with the multivariate test (Λ = 0.94, $F_{2,25} < 1$, $p > .50$).

The results of the more powerful adjusted univariate tests for both the occasion effect ($F_{1.78, 46.32} = 2.09$, $p > .15$) and interaction effect ($F_{1.78, 46.32} < 1$, $p > .59$) corroborate the results of the multivariate tests (Appendix AA.1).

ATRI (Amplitude Tremor Intensity Index)

Examination of the measure ATRI of the spoken /u/ vowel indicated that neither the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females, nor the sphericity assumption was met. Therefore, the multivariate approach was used to examine ATRI. Analysis determined that the main effect of occasion was present for the dependent variable ATRI.

There was no difference between males and females of the variable ATRI ($F_{1,26} = 3.76$, $p > .05$). Wilks' Lambda (Λ = 0.65) indicated that there was a significant difference over occasion ($F_{2,25} = 6.61$, $p < .01$). The value of eta squared indicated that 34% of the variability in ATRI of spoken /u/, pooled over genders, was aligned with testing occasion. The power of this test was 0.87 which indicates that the alignment is due to more than chance. From the independent trend components, both significant linear trend ($F_{1,26} = 9.54$, $p < .01$) and quadratic trend ($F_{1,26} = 11.77$, $p < .01$) over the three testing occasions were found. The combined pattern is somewhat J-shaped, starting high, and decreasing over time.

Finally, no interaction between gender and occasion was detected with the multivariate approach ($\Lambda = 0.94$, $F_{2,25} < 1$, $p > .45$) (Appendix AA.2).

Fftr (F_o Tremor Frequency)

Examination of the measure Fftr of the spoken /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was not met; however, the sphericity assumption was met. Therefore, the multivariate approach was used to examine Fftr. The analysis determined that no main or interaction effects were present for the dependent variable Fftr.

There was no difference between males and females on the variable Fftr ($F_{1,26} = 1.42$, $p > .20$). There was no difference ($\Lambda = 0.92$, $F_{2,25} = 1.01$, $p > .35$) over testing occasion (repeated measures). Finally, there was there was no interaction between gender and occasion detected with the multivariate test ($\Lambda = 0.94$, $F_{2,25} < 1$, $p > .45$).

The results of the more powerful adjusted univariate tests for occasion effect ($F_{1.74, 45.13} = 1.37$, $p > .25$) and interaction effect ($F_{1.74, 45.13} < 1$, $p > .40$) corroborate the results of the multivariate tests (Appendix AA.3).

Fatr (Amplitude Tremor Frequency)

Examination of the measure Fatr of the spoken /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was met; and the sphericity assumption was met. Therefore, the univariate approach was used to examine Fatr.

There was no difference between males and females of the variable Fatr ($F_{1,26} < 1$, $p > .80$), and no difference over occasion was found ($F_{2,52} = 1.31$, $p > .25$). Finally, there was there was no interaction between gender and occasion detected with the univariate approach ($F_{2,52} = 1.04$, $p > .35$) (Appendix AA.4).

Sung Phonation of the /u/ vowel

Fundamental Frequency Measures

F_o (Fundamental Frequency)

Examination of the measure F_O of the sung /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was not met; however, the sphericity assumption was met. Therefore, the multivariate approach was used to examine F_O. The analysis determined that there was a main effect for gender present for the dependent variable F_O.

Males scored significantly lower than did females on the variable F_O ($F_{1,26} = 55.23$, $p < .001$). Males scored significantly lower than did females. The value of eta squared indicated that 68% of the variability pooled over occasions was aligned with gender. The power rating was at maximum strength; 1.0. There was no difference over testing occasion ($\Lambda = 0.99$, $F_{2,25} < 1$, $p > .80$).

Finally, no interaction between gender and occasion was detected ($\Lambda = 0.95$, $F_{2,25} < 1$, $p > .50$) (Appendix BB.1).

Jita (Absolute Jitter in us)

Examination of the measure Jita of the sung /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was met. However, the sphericity assumption was not met. Therefore, the multivariate approach was used to examine Jita. The analysis determined that both main effects for gender and occasion were present for the dependent variable Jita.

Males scored significantly higher than females on the variable Jita ($F_{1,26} = 11.76$, $p < .01$). The value of eta squared indicated that 31% of the variability pooled over occasions was aligned with gender. Wilks' Lambda ($\Lambda = 0.33$)

indicated that there was a significant difference over testing occasion ($F_{2,25}$ = 24.64, $p < .001$). The value of eta squared indicated that 66% of the variability in Jita of sung /u/, pooled over gender, was aligned with testing occasion (the repeated measures). The more dramatic effect was that of testing occasion; it was stronger than the gender effect by a ratio of more than 2:1, as well as having maximum power (1.0) vs. a power of .90. From the independent trend components, both a significant downward linear trend ($F_{1,26}$ = 50.89, $p < .001$) over the three testing occasions and a significant quadratic trend ($F_{1,26}$ = 20.03, $p < .001$) were found. The significant downward linear trend indicates that Jita decreased over time. The positive quadratic component indicates that although Jita decreased over time, it bottomed out and slightly increased from occasion two to occasion three. The linear trend was stronger than the quadratic component (66% to 44%); however, the respective powers were almost equal (1.0 to 0.99). These two independent components of trend reflect a dramatic training effect over time.

The results of the Greenhouse-Geisser adjusted univariate approach for the effect of testing occasion ($F_{1.52, 39.62}$ = 36.64, $p < .001$) support the results of the multivariate approach. However, the univariate approach indicated that there was an interaction between gender and testing occasion ($F_{1.52, 39.62}$ = 4.37, $p <$ .02). The value of eta squared indicated that 14% of the variability in Jita of sung /u/ was aligned with the interaction between gender and testing occasion. However, the power was 0.73 which indicated that the alignment was due to only slightly more than chance.

By comparison there was no interaction between gender and occasion detected with the less powerful multivariate test (Λ = 0.80, $F_{2,25}$ = 2.99, $p > .60$) (Appendix BB.2).

Jitt (Jitter Percent)

Examination of the measure Jitt of the sung /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was met. However, the sphericity assumption was not met. Therefore, the multivariate approach was used to examine Jitt. Analysis determined that the main effect of occasion was present for the dependent variable Jitt.

There was no difference between males and females of the variable Jitt ($F_{1,26} = 2.13$, $p > .15$). Wilks' Lambda ($\Lambda = 0.38$) indicated that there was a significant difference over testing occasion ($F_{2,25} = 20.04$, $p < .001$). The value of eta squared indicated that 61% of the variability in Jitt of sung /u/, pooled over gender, was aligned with testing occasion (the repeated measures). The power of the effect was at maximum strength; 1.0. From the independent tests of trend components, a significant downward linear trend ($F_{1,26} = 40.28$, $p < .001$) over the three testing occasions and a significant positive quadratic trend ($F_{1,26} = 19.55$, $p < .001$) were found. The significant downward linear trend indicates that Jitt decreased over time. The positive quadratic component indicates that although Jitt decreased over time, it bottomed out and slightly increased from occasion two to occasion three. The linear trend was stronger than the quadratic component (60% to 43%), however, these powers were almost equal (0.99 to 0.98 respectively).These two independent components of trend reflect a dramatic training effect over time.

The results of applying the Greenhouse-Geisser adjusted univariate tests ($F_{1.52, 39.44} = 31.98$, $p < .001$) corroborated the results of the multivariate tests. Finally, there was there was no interaction between gender and occasion detected with either the adjusted univariate ($F_{1.52, 39.44} < 1$, $p > .85$) or multivariate ($\Lambda = 0.99$, $F_{2,25} = < 1$, $p > .90$) approach (Appendix BB.3).

RAP (Relative Average Perturbation)

Examination of the measure RAP of the sung /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was met; however, the sphericity assumption was not met. Therefore, the multivariate approach was used to examine RAP. The analysis determined that both main effects for gender and occasion were present for the dependent variable RAP.

Females scored significantly higher than males on the variable RAP ($F_{1,26} = 5.10$, $p < .05$). The value of eta squared indicated that 16% of the variability in RAP of sung /u, pooled over occasion, was aligned with gender. However, the power of the test was 0.58 which indicated that the alignment was most likely due to chance. Wilks' Lambda ($\Lambda = 0.38$) indicated that there was a significant difference over testing occasion ($F_{2,25} = 20.38$, $p < .001$). The value of eta squared indicated that 62% of the variability in RAP of sung /u/, pooled over gender, was aligned with testing occasion (the repeated measures). The power of the effect was at maximum strength; 1.0. Therefore, the more dramatic effect was that of testing occasion which was stronger than the gender effect by a ratio of almost 4:1; also, the power rating was almost doubled. From the independent tests of trend components, a significant downward linear trend ($F_{1,26} = 41.22$, $p < .001$) over the three testing occasions and a significant positive quadratic trend ($F_{1,26} = 18.25$, $p < .001$) were found. The significant downward linear trend indicates that RAP decreased over time. The positive quadratic component indicates that although RAP decreased over time, it bottomed out and slightly increased from occasion two to occasion three. The linear trend was stronger than the quadratic component (61% to 41%); however, the power of the two tests was almost equal (0.99 to 0.98 respectively). These two independent components of trend reflect a dramatic training effect over time.

The results of the adjusted univariate test ($F_{1.54, 40.04} = 31.93$, $p < .001$) corroborate the results of the multivariate test. Finally, there was no interaction between gender and occasion detected with either the adjusted univariate ($F_{1.54, 40.04} < 1$, $p > .85$) or multivariate ($\Lambda = 0.98$, $F_{2,25} < 1$, $p > .80$) approaches (Appendix BB.4).

PPQ (Pitch Perturbation Quotient)

Examination of the measure PPQ of the sung /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was met; however, the sphericity assumption was not met. Therefore, the multivariate approach was used to examine PPQ. The analysis determined that a main effect for occasion was present for the dependent variable PPQ.

Males were indistinguishable from females on the variable PPQ ($F_{1,26} = 3.45$ $p > .05$). Wilks' Lambda ($\Lambda = 0.36$) indicated that there was a significant difference over testing occasion ($F_{2,25} = 21.30$, $p < .001$). The value of eta squared indicated that 63% of the variability in PPQ of sung /u/, pooled over genders, was aligned with testing occasion (the repeated measures). The power of the effect was at maximum strength: 1.0. From the independent tests of trend components, a significant downward linear trend ($F_{1,26} = 43.84$, $p < .001$) over the three testing occasions and a significant positive quadratic trend ($F_{1,26} = 21.53$, $p < .001$) were found. The significant downward linear trend indicates that RAP decreased over time. The positive quadratic component indicates that although RAP decreased over time, it bottomed out and slightly increased from occasion two to occasion three. The linear trend was stronger than the quadratic component (62% to 45%); however, the respective powers were almost equal (1.0

to 0.99). These two independent components of trend reflect a dramatic training effect over time.

The results of the adjusted univariate test ($F_{1.41, 36.68} = 35.32$, $p < .001$) corroborate the results of the multivariate test. Finally, there was there was no interaction between gender and occasion detected with either the adjusted univariate ($F_{1.41, 36.68} < 1$, $p > .85$) or multivariate ($\Lambda = 0.98$, $F_{2,25} < 1$, $p > .80$) approaches (Appendix BB.5).

sPPQ (Smoothed Pitch Perturbation Quotient)

Examination of the measure sPPQ of the sung /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was met; however, the sphericity assumption was not met. Therefore, the multivariate approach was used to examine sPPQ. The analysis determined that both main effects for gender and occasion were present for the dependent variable sPPQ.

Males scored significantly higher than females on the variable sPPQ ($F_{1,26} = 9.21$, $p < .01$). The value of eta squared indicated that 26% of the variability in sPPQ of sung /u/, pooled over occasions, was aligned with gender. The power of the test was 0.83. Wilks' Lambda ($\Lambda = 0.54$) indicated that there was a significant difference over testing occasion ($F_{2,25} = 10.54$, $p < .001$). The value of eta squared indicated that 45% of the variability in sPPQ of sung /u/, pooled over gender, was aligned with testing occasion (the repeated measures). The power of the effect was nearly at a maximum strength of 0.98. The more dramatic effect was that of testing occasion. It was stronger than the gender effect by a ratio of nearly 2:1, and the power of the tests was 0.98 vs. 0.83. From the independent tests of trend components, both a significant linear trend ($F_{1,26} = 8.76$, $p < .01$) and a positive quadratic trend ($F_{1,26} = 15.97$, $p < .001$) were found. The positive

quadratic component indicates that sPPQ decreased from occasion one to occasion two, and increased from occasion two to occasion three. When coupled with the less dramatic decreasing linear trend, these independent components of trend reflects a dramatic training effect over time.

The results of the adjusted univariate test ($F_{1.65, 42.77} = 10.75$, $p < .001$) corroborate the results of the multivariate test. Finally, there was no interaction between gender and occasion detected with either the adjusted univariate ($F_{1.65, 42.77} < 1$, $p > .50$) or multivariate ($\Lambda = 0.96$, $F_{2,25} < 1$, $p > .60$) approaches (Appendix BB.6).

vFo (Fundamental Frequency Variation)

Examination of the measure vFo of the sung /u/ vowel indicated that both the assumptions of homogeneity of variance-covariance matrices of the three occasions between males and females and the sphericity assumption were met. Therefore, the univariate approach was used to examine vFo. The analysis determined that a main effect for occasion was present for the dependent variable vFo.

Males were indistinguishable from females on the variable vFo ($F_{1,26} < 1$, $p > .35$). There was a significant difference over testing occasion ($F_{2,52} = 12.79$, $p < .001$). The value of eta squared indicated that 33% of the variability in vFo of sung /u/, pooled over gender, was aligned with testing occasion (the repeated measures). The power of the effect was nearly maximum strength: 0.99. From the independent tests of trend components, both a significant linear trend ($F_{1,26} = 12.34$, $p < .001$) over the three testing occasions and a significant quadratic trend ($F_{1,26} = 13.79$, $p < .001$) were found. The stronger positive quadratic trend (35% vs. 32% eta squared) in the presence of a downward linear trend indicates a decreasing asymptotic pattern over the training program.

Finally, there was there was no interaction between gender and occasion detected with the univariate test ($F_{2,52} < 1$, $p > .55$) (Appendix BB.7).

Amplitude Measures

ShdB (Shimmer in decibels)

Examination of the measure ShdB of the sung /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was met; however, the sphericity assumption was not met. Therefore, the multivariate approach was used to examine ShdB. The analysis determined that both main effects for gender and occasion were present for the dependent variable ShdB.

Males scored significantly higher than females on the variable ShdB ($F_{1,26} = 9.80$, $p < .01$). The value of eta squared indicated that 27% of the variability in ShdB of sung /u/, pooled over occasions, was aligned with gender. The power of the test was 0.85. Wilks' Lambda ($\Lambda = 0.37$) indicated that there was a significant difference over testing occasion ($F_{2,25} = 21.05$, $p < .001$). The value of eta squared indicated that 62% of the variability in ShdB of sung /u/, pooled over gender, was aligned with testing occasion (the repeated measures). The power of the effect was at maximum strength: 1.0. The more dramatic effect was that of testing occasion. It was stronger than the gender effect by a ratio of more than 2:1, and the power of the tests was 1.0 vs. .85. From the tests of independent trend components, a significant downward linear trend ($F_{1,26} = 28.57$, $p < .001$) and a positive quadratic trend ($F_{1,26} = 35.38$, $p < .001$) over the three testing occasions were found. The downward linear trend indicates that ShdB decreased over time. The positive quadratic component indicates that although ShdB decreased over time, it bottomed out and increased from occasion two to occasion three. The linear trend and quadratic are nearly equal in strength; 52% and 57%

respectively, and the tests posses equivalent power (0.99). These two independent components of trend reflect a dramatic training effect over time.

The results of the adjusted univariate test ($F_{1.42, 36.97} = 30.31$, $p < .001$) corroborate the results of the multivariate test. Finally, there was no interaction between gender and occasion detected with the adjusted univariate ($F_{1.42, 36.97} = 1.82$, $p > .15$) or multivariate test ($\Lambda = 0.88$, $F_{2,25} = 1.69$, $p > .20$) (Appendix CC.1).

Shim (Shimmer Percent)

Examination of the measure Shim of the sung /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was met; however, the sphericity assumption was not met. Therefore, the multivariate approach was used to examine Shim. The analysis determined that both main effects for gender and occasion were present for the dependent variable Shim.

Males scored significantly higher than females on the variable Shim ($F_{1,26} = 13.61$, $p < .01$). The value of eta squared indicated that 34% of the variability pooled over occasions was aligned with gender. The strength of the test was near maximum at 0.94. Wilks' Lambda ($\Lambda = 0.31$) indicated that there was a significant difference over testing occasion ($F_{2,25} = 26.96$, $p < .001$). The value of eta squared indicated that 68% of the variability in Shim of sung /u/, pooled over gender, was aligned with testing occasion (the repeated measures). The more dramatic effect was that of testing occasion. It was stronger than the gender effect by a ratio of 2:1, as well as possessing a test with maximum power (1.0) compared to a power of 0.94. From the tests of independent trend components, a significant downward linear trend ($F_{1,26} = 35.07$, $p < .001$) over the three testing occasions and a significant quadratic trend ($F_{1,26} = 39.68$, $p < .001$) were

found. The significant downward linear trend indicates that Shim decreased over time. The positive quadratic component indicates that although Shim decreased over time, it bottomed out and slightly increased from occasion two to occasion three. The quadratic component was slightly stronger than the linear trend (60% to 57%); however, the tests possessed equivalent power (0.99). These two independent components of trend reflect a dramatic training effect over time.

The results of the adjusted univariate test ($F_{1.54, 40.06} = 36.62$, $p < .001$) for the effect of testing occasion corroborate the results of the multivariate test. Moreover, the more powerful (0.70) adjusted univariate approach indicated that there was an interaction between gender and testing occasion ($F_{1.54, 40.06} = 4.06$, $p < .05$). The value of eta squared indicated that 13% of the variability in Shim of sung /u/ was aligned with the interaction between gender and testing occasion. However, the less powerful ((0.50) multivariate test did not indicate a significant interaction ($\Lambda = 0.81$, $F_{2,25} = 2.77$, $p > .08$) (Appendix CC.2).

APQ (Amplitude Perturbation Quotient)

Examination of the measure APQ of the sung /u/ vowel indicated that neither the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females, nor the sphericity assumption was met. Therefore, the multivariate approach was used to examine APQ. The analysis determined that both main effects for gender and occasion as well as the interaction of gender and testing occasion were all present for the dependent variable APQ.

Males scored significant higher than the females on the variable APQ ($F_{1,26} = 15.81$, $p < .001$). The value of eta squared indicated that 37% of the variability in APQ of sung /u/, pooled over occasions, was aligned with gender. The strength of the test was near maximum at 0.96. Wilks' Lambda ($\Lambda = 0.26$)

indicated that there was a significant difference over testing occasion ($F_{2,25}$ = 34.25, $p < .001$). The value of eta squared indicated that 73% of the variability in APQ of sung /u/, pooled over gender, was aligned with testing occasion (the repeated measures). From the independent tests of trend components, a significant downward linear trend ($F_{1,26} = 36.05$, $p < .001$) over the three testing occasions and a significant positive quadratic trend ($F_{1,26} = 55.81$, $p < .001$) were found. The significant downward linear trend indicates that APQ decreased over time. The positive quadratic component indicates that although APQ decreased over time, it bottomed out and slightly increased from occasion two to occasion three. The quadratic component was 10% stronger than the linear trend (68% to 58%); however, the powers were nearly equal (1.0 and 0.99 respectively). These two independent components of trend reflect a dramatic training effect over time.

Wilks' Lambda ($\Lambda = 0.65$) indicated that there was an interaction between gender and testing occasion (the repeated measures). The value of eta squared indicated that 34% of the variability in APQ of sung /u/ was aligned with the interaction between gender and testing occasion ($F_{2,25} = 6.48$, $p < .01$). The specific pattern of the interaction was a diminishing difference between males and females that progressively decreased by a half over the three occasions. This implied that, although the males consistently scored higher than females, they converged over time.

The more dramatic effect was that of testing occasion. It was stronger than the gender effect by a ratio of nearly 2:1, as well as having tests with maximum power (1.0) vs. a power of .97. It was also stronger than the interaction effect by a ratio of 2:1 and a power of maximum strength of 1.0 vs. 0.87. The results of the univariate approach support the results of the multivariate approach but with more power (Appendix CC.3).

sAPQ (Smoothed Amplitude Perturbation Quotient)

Examination of the measure sAPQ of the sung /u/ vowel indicated that neither the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females, nor the sphericity assumption was met. Therefore, the multivariate approach was used to examine sAPQ. The analysis determined that the main effect of occasion and the interaction effect between gender and testing occasion were present for the dependent variable sAPQ.

There was no difference between males and females of the variable APQ ($F_{1,26} < 1$, $p > .80$). Wilks' Lambda ($\Lambda = 0.54$) indicated that there was a significant difference over testing occasion ($F_{2,25} = 10.31$, $p < .01$). The value of eta squared indicated that 45% of the variability in sAPQ of sung /u/, pooled over gender, was aligned with testing occasion (the repeated measures). From the independent tests of trend components, a significant downward linear trend ($F_{1,26} = 17.87$, $p < .001$) and a significant positive quadratic trend ($F_{1,26} = 11.19$, $p < .01$) over the three testing occasions were detected. The strength of the two trends were 40% and 30% for eta squared respectively. The two trends are indicative of a decreasing asymptotic pattern over time.

Wilks' Lambda ($\Lambda = 0.77$) indicated that there was an interaction between gender and testing occasion (the repeated measures). The value of eta squared indicated that 22% of the variability in sAPQ of sung /u/ was aligned with the interaction between gender and testing occasion ($F_{2,25} = 3.53$, $p < .05$). However, the power of this test was 0.60, indicating that the alignment was most likely due to chance. There was a significant positive quadratic ($F_{1,26} = 7.08$, $p < .05$) component to the interaction effect. Its eta square of 21% virtually exhausted all the interaction variability. The specific nature of the interaction was disordinal (Lubin, 1962). Females exceeded males on occasion one by the same amount that

females were exceeded by males on occasion two, with males exceeding females again on occasion three. There was a general decline across all three occasions of the combined averages.

The more dramatic effect was that of testing occasion. It was stronger than the interaction effect by a ratio of more than 2:1 as well as having more power (0.98 vs. a power of 0.60). From the independent trend components, a significant downward linear trend ($F_{1,26} = 17.87$, $p < .001$) over the three testing occasions was found. The significant downward linear trend indicates that sAPQ decreased over time.

The results of the adjusted univariate test for testing occasion ($F_{1.46, 38.04} = 16.25$, $p < .001$) corroborate the results of the multivariate test. However the adjusted univariate test indicated that there was no interaction between gender and testing occasion ($F_{1.46, 38.04} = 1.93$, $p > .15$) (Appendix CC.4).

vAm (Peak-Amplitude Variation)

Examination of the measure vAm of the sung /u/ vowel indicated that neither the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females, nor the sphericity assumption was met. Therefore, the multivariate approach was used to examine vAm. The analysis determined that both main effects for gender and occasion were present for the dependent variable vAm.

Females scored significantly higher than males on the variable vAm ($F_{1,26} = 7.84$, $p < .05$). The value of eta squared indicated that 23% of the variability in vAm of sung /u/, pooled over testing occasions, was aligned with gender. The power of the gender effect test was 0.76. This indicated that the alignment was due to slightly better than chance. Wilks' Lambda ($\Lambda = 0.62$) indicated that there was a significant difference over testing occasion ($F_{2,25} = 7.43$, $p < .01$). The

value of eta squared indicated that 37% of the variability in vAm of sung /u/, pooled over gender, was aligned with testing occasion (the repeated measures). The more dramatic effect was that of testing occasion. It was stronger than the gender effect by 14% as well as having more power (0.91 vs. a power of 0.76). From the independent tests of trend components, a significant downward linear trend ($F_{1,26} = 14.56$, $p < .001$) over the three testing occasions and a significant positive quadratic trend ($F_{1,26} = 8.44$, $p < .01$) were found. The linear trend was half again as strong as the quadratic trend (36% vs. 24%). The combination of the two suggests a decreasing asymptotic pattern over the training program. This pattern for vAm reflects a dramatic training effect over time.

The results of the adjusted univariate ($F_{1.33, 34.55} = 13.14$, $p < .001$) corroborate the results of the multivariate test. Finally, there was no interaction between gender and occasion detected with the adjusted univariate ($F_{1.33, 34.55} = 2.09$, $p > .10$) or multivariate test ($\Lambda = 0.83$, $F_{2,25} = 2.52$, $p > .05$) (Appendix CC.5).

Noise Related Measures

NHR (Noise to Harmonic Ratio)

Examination of the measure NHR of the sung /u/ vowel indicated that neither the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females, nor the sphericity assumption was met. Therefore, the multivariate approach was used to examine NHR. The analysis determined that the main effect of gender was present for the dependent variable NHR.

Males scored significantly higher than females on the variable NHR ($F_{1,26} = 22.28$, $p < .001$). The value of eta squared indicated that 46% of the variability in NHR of sung /u/, pooled over testing occasions, was aligned with gender. The

power of the gender effect was nearly at maximum strength; 0.99. There was no difference over testing occasion ($\Lambda = 0.92$, $F_{2,25} = 1.08$, $p > .30$).

Finally, there was no interaction between gender and testing occasion detected with the multivariate ($\Lambda = 0.83$, $F_{2,25} = 2.48$, $p > .10$) approach (Appendix DD.1).

VTI (Voice Turbulence Index)

Examination of the measure VTI of the sung /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices over the three occasions between males and females was not met; however, the sphericity assumption was met. Therefore, both the univariate and multivariate approaches were used to examine VTI. The analyses determined that the main effect of gender, and the interaction between gender and testing occasion, were present for the dependent variable VTI.

Males scored significantly higher than females on the variable VTI ($F_{1,26} = 5.50$, $p < .05$). The value of eta squared indicated that 17% of the variability in VTI of sung /u/, pooled over testing occasions, was aligned with gender. The power of the gender effect was 0.61. This indicated that the alignment was most likely due to chance. There was no difference over testing occasion using either the univariate test ($F_{2,52} = 0.02$, $p > .95$) or the multivariate test ($\Lambda = 0.99$, $F_{2,25} = 0.02$, $p > .95$).

Finally, both the univariate and multivariate approaches detected that there was an interaction between gender and testing occasion. The univariate test indicated that there was an interaction between gender and testing occasion ($F_{2,52} = 3.42$, $p < .05$). The value of eta squared indicated that 11% of the variability in VTI of sung /u/ is aligned with the interaction effect. However, the power rating, 0.61, indicates that the alignment is most likely due to chance.

Wilks' Lambda (Λ = 0.74, $F_{2,25}$ = 4.26, $p < .05$) also indicated that there was a significant interaction between gender and occasion. The nature of the interaction was ordinal with an ever widening difference over the three testing occasions, and the average of males eventually doubled that of females (Appendix DD.2).

SPI (Soft Phonation Index)

Examination of the measure SPI of the sung /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices over the three occasions between males and females was not met; however, the sphericity assumption was met. Therefore, both the univariate and multivariate approaches were used to examine SPI. The analyses determined that the main effect of gender was present for the dependent variable SPI.

Females scored significantly higher than males (in general twice that of females) on the variable SPI ($F_{1,26}$ = 7.86, $p < .01$). The value of eta squared indicated that 23% of the variability in SPI of sung /u/, pooled over testing occasions, was aligned with gender. The power of the gender effect was 0.76. This indicated that the alignment was most likely due to something other than chance. There was no difference over testing occasion using either the univariate test ($F_{2,25}$ = 4.82, $p < .05$) or the multivariate test (Λ = 0.88, $F_{2,25}$ = 1.62, $p > .20$).

Finally, there was no interaction between gender and testing occasion detected with either the univariate test ($F_{2,52}$ = 2.58, $p > .05$) or multivariate test (Λ = 0.91, $F_{2,25}$ = 1.12, $p > .30$) (Appendix DD.3).

Tremor Related Measures

FTRI (F_0 Tremor Intensity Index)

Examination of the measure FTRI of the sung /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was met; however, the sphericity assumption was not met. Therefore, the multivariate approach was used to examine FTRI. The analysis determined that a main effect for occasion was present for the dependent variable FTRI.

There was no difference between males and females on the variable FTRI ($F_{1,26} = 2.25$, $p > .10$). Wilks' Lambda ($\Lambda = 0.78$) indicated that there was a significant difference over testing occasion ($F_{2,25} = 3.42$, $p < .05$). The value of eta squared indicated that 22% of the variability in FTRI of sung /u/, pooled over gender, was aligned with testing occasion (the repeated measures). The power of the effect was 0.59. This indicates that the alignment was most likely due to chance. From the two independent tests of trend components, only a significant positive quadratic trend ($F_{1,26} = 4.69$, $p < .05$) over the three testing occasions was found. This indicates that FTRI decreased, bottomed out, then ascended over time and reflects a dramatic training effect during the program.

Finally, there was no interaction between gender and occasion detected ($\Lambda = 0.97$, $F_{2,25} = < 1$, $p > .70$) with the multivariate test (Appendix EE.1).

ATRI (Amplitude Tremor Intensity Index)

Examination of the measure ATRI of the sung /u/ vowel indicated that neither the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females, nor the sphericity assumption was met. Therefore, the multivariate approach was used to examine ATRI. The

analysis determined that both main effects for gender and occasion were present for the dependent variable ATRI.

Females scored significantly higher than males on the variable ATRI ($F_{1,26} = 5.47$, $p < .05$). The value of eta squared indicated that 17% of the variability in ATRI of sung /u/, pooled over testing occasions, was aligned with gender. The power of the gender effect was 0.61. This indicated that the alignment was most likely due to chance. Wilks' Lambda ($\Lambda = 0.72$) indicated that there was a significant difference over testing occasion ($F_{2,25} = 4.82$, $p < .05$). The value of eta squared indicated that 27% of the variability in ATRI of sung /u/, pooled over gender, was aligned with testing occasion (the repeated measures). The power of the effect was 0.75. The more dramatic effect was that of testing occasion. It was stronger than the gender effect by 10%. However, the tests of both effects were low in power (0.61 and 0.75 respectively). From the tests of independent trend components, only a significant linear trend ($F_{1,26} = 9.92$, $p < .01$) over the three testing occasions was found.

The results of the adjusted univariate test ($F_{1.39, 36.13} = 8.33$, $p < .001$) corroborate the results of the multivariate approach. Finally, there was no interaction between gender and testing occasion detected with the adjusted univariate ($F_{1.39, 36.13} = 2.58$, $p > .05$) or multivariate ($\Lambda = 0.79$, $F_{2,25} = 3.31$, $p > .05$) tests (Appendix EE.2).

Fftr (F_o Tremor Frequency)

Examination of the measure Fftr of the sung /u/ vowel indicated that both the assumptions of homogeneity of variance-covariance matrices over the three occasions between males and females and sphericity were met. Therefore, the univariate approach was used to examine Fftr. Analysis determined that the main effect of occasion was present for the dependent variable Fftr.

The males were indistinguishable from the females on the variable Fftr ($F_{1,26} < 1$, $p > .45$). There was a significant difference over testing occasion ($F_{2,52} = 5.36$, $p < .01$). The value of eta squared indicated that 17% of the variability in Fftr of sung /u/, pooled over gender, was aligned with testing occasion (the repeated measures). The power of the effect was 0.82. This indicates that the alignment is most likely due to something other than chance. From the tests of independent trend components, only a significant linear trend ($F_{1,26} = 9.80$, $p < .01$) over the three testing occasions was found.

Finally, there was no interaction between gender and occasion detected ($F_{2,52} = 2.71$, $p > .071$) (Appendix EE.3).

Fatr (Amplitude Tremor Frequency)

Examination of the measure Fatr of the sung /u/ vowel indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was not met; however, the sphericity assumption was met. Therefore, the univariate approach was used to examine Fatr. The analysis determined that the main effect of occasion was present for the dependent variable Fatr.

There was no difference between males and females of the variable Fatr ($F_{1,26} < 1$, $p > .40$). There was a significant difference over testing occasion ($F_{2,52} = 4.53$, $p < .05$). The value of eta squared indicated that 14% of the variability in Fatr of sung /u/, pooled over gender, was aligned with testing occasion (the repeated measures). The power of the effect was 0.74. This indicated that the alignment was due to slightly more than chance. From the tests of independent trend components, only a significant downward linear trend ($F_{1,26} = 8.49$, $p < .01$) over the three testing occasions was found. This slight

downward pattern suggests a residual practice effect over the duration of the program.

Finally, there was no interaction between gender and testing occasion detected with the univariate test ($F_{2,52} = 1.72$, $p > .15$) (Appendix EE.4).

Phonatory Measures

Spoken Phonation

Conversational Fundamental Frequency (Average Fo)

Examination of the measure average F_O of the Marvin Williams passage indicated that both the assumptions of homogeneity of variance-covariance matrices of the three occasions between males and females and the sphericity assumption were met. Therefore, the univariate approach was used to examine average F_O. The analysis determined that a main effect of gender was present for the dependent variable average F_O.

Females scored significantly higher than males on the variable average F_O ($F_{1,26} = 120.65$, $p < .001$). The value of eta squared indicated that 82% of the variability in average F_O of Marvin Williams, pooled over testing occasions, was aligned with gender. The power of the test for the gender effect was maximized at 1.0. There was no difference over testing occasion ($F_{2,52} < 1$, $p > .50$). Finally, there was no interaction between gender and testing occasion ($F_{2,52} = 1.92$, $p > .15$) (Appendix FF.1).

Physiological Frequency Range of Phonation - High (PFRPH)

Examination of the measure PFRPH indicated that neither the assumption of homogeneity of variance-covariance matrices over the three occasions between males and females, nor the sphericity assumption was met. Therefore, the multivariate approach was used to examine PFRPH. The analysis determined that

the main effects for both gender and occasion were present for the dependent variable PFRPH.

Females scored significantly higher than males on the variable PFRPH ($F_{1,26} = 86.08$, $p < .001$). The value of eta squared indicated that 76% of the variability in PFRPH, pooled over testing occasions, was aligned with gender. The power of the test of the gender effect was at maximized at 1.0. Wilks' Lambda ($\Lambda = 0.60$) indicated that there was a significant difference over testing occasion ($F_{2,25} = 8.05$, $p < .01$). The value of eta squared indicated that 39% of the variability in PFRPH, pooled over gender, was aligned with testing occasion (repeated measures). The power of the test for this effect was 0.93. The more dramatic effect is that of gender. It is stronger than the test of occasion effect by a ratio of almost 2:1, and the test has more power (1.0 vs. 0.93). From the tests of independent trend components, both a significant linear trend ($F_{1,26} = 13.99$, $p < .001$) over the three testing occasions and a negative quadratic trend ($F_{1,26} = 8.01$, $p < .01$) were found. The combination of these trends suggests a gradual slowing increase, resembling a learning curve, over the three occasions. Finally, there was no interaction between gender and testing occasion ($\Lambda = 0.98$, $F_{2,25} < 1$, $p > .85$) (Appendix FF.2).

Physiological Frequency Range of Phonation - Low (PFRPL)

Examination of the measure PFRPL indicated that neither the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females, nor the sphericity assumption was met. Therefore, the multivariate approach was used to examine PFRPL. The analysis determined that main effects for both gender and occasion were present for the dependent variable PFRPL.

Females scored significantly higher (nearly doubling) than males on the variable PFRPL ($F_{1,26} = 112.91$, $p < .001$). The value of eta squared indicated that 81% of the variability in PFRPL, pooled over testing occasions, was aligned with gender. The power of the test of the gender effect was at maximized at 1.0. Wilks' Lambda ($\Lambda = 0.97$) indicated that there was no difference over testing occasion ($F_{2,25} < 1$, $p > .75$). Finally, there was no interaction between gender and testing occasion ($\Lambda = 0.95$, $F_{2,25} < 1$, $p > .50$) (Appendix FF.3).

Physiological Frequency Range of Phonation - Semitones (PFRPS)

Examination of the measure PFRPS indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was not met; however, the sphericity assumption was met. Therefore, the multivariate approach was used to examine PFRPS. The analysis determined that the main effects for both gender and occasion were present for the dependent variable PFRPS.

Males scored significantly higher than females on the variable PFRPS ($F_{1,26} = 7.52$, $p < .05$). The value of eta squared indicated that 22% of the variability in PFRPS, pooled over testing occasions, was aligned with gender. The power of the test of the gender effect was 0.75. There was a significant difference over testing occasion ($\Lambda = 0.72$, $F_{2,25} = 4.74$, $p < .05$). The value of eta squared indicated that 28% of the variability in PFRPS, pooled over gender, was aligned with testing occasion (repeated measures). The power of the test of this effect was 0.87. The occasion effect was nearly 1 1/2 the strength of the gender effect (28%). From the tests of independent trend components, both a significant linear trend ($F_{1,26} = 7.04$, $p < .02$) and a significant negative quadratic trend ($F_{1,26} = 4.45$, $p < .05$) over the three testing occasions were found. This indicates a decelerated

increasing pattern similar to a learning or practice curve over the three occasions. Finally, there was no interaction between gender and testing occasion (Λ = 0.98, $F_{2,25} < 1$, $p > .85$) (Appendix FF.4).

Maximum Phonation Time Spoken /a/ (MPT /a/)

Examination of the measure MPT of spoken /a/ indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was met; however, the sphericity assumption was not met. Therefore, the multivariate approach was used to examine MPT of spoken /a/. The analysis determined that a main effect for both gender and occasion were present for the dependent variable MPT of spoken /a/.

Males scored significantly higher than females on the variable MPT of spoken /a/ ($F_{1,26} = 6.33$ $p < .02$). The value of eta squared indicated that 19% of the variability in MPT of spoken /a/, pooled over testing occasions, was aligned with gender. The power of the gender effect was 0.67. This indicates that the alignment was most likely due to no more than chance. Wilks' Lambda (Λ = 0.54) indicated that there was a significant difference over testing occasion ($F_{2,25}$ = 10.44, $p < .001$). The value of eta squared indicated that 45% of the variability in MPT of spoken /a/, pooled over gender, was aligned with testing occasion (repeated measures). The power of the test for this effect was nearly at a maximum, 0.98. From the tests of independent trend components, a significant upward linear trend ($F_{1,26} = 19.22$, $p < .001$) over the three testing occasions was found. The upward linear trend indicates that MPT of spoken /a/ increased from testing one to testing three. This pattern reflects that there was a dramatic training effect over time. Finally, there was no interaction between gender and testing occasion (Λ = 0.90, $F_{2,25} = 1.26$, $p > .25$) (Appendix FF.5).

Maximum Phonation Time Spoken /i/ (MPT /i/)

Examination of the measure MPT of spoken /i/ indicated that both the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females and the sphericity assumption were met. Therefore, the univariate approach was used to examine MPT of spoken /i/. The analysis determined that a main effect for occasion was present for the dependent variable MPT of spoken /i/.

There was no difference between males and females of the variable MPT of spoken /i/ ($F_{1,26} = 3.99$ $p > .05$). There was a significant difference over testing occasions ($F_{2,52} = 7.97$ $p < .01$). The value of eta squared indicated that 23% of the variability in MPT of spoken /i/, pooled over gender, was aligned with testing occasion (repeated measures). The power of the test for this effect was nearly at its maximum, 0.94. From the tests of independent trend components, only a significant upward linear trend ($F_{1,26} = 15.55$, $p < .001$) over the three testing occasions was found. The upward linear trend indicates that MPT of spoken /i/ increased from testing one to testing three. This pattern reflects that there was a dramatic training effect over time. Finally, there was no interaction between gender and testing occasion ($F_{2,52} = 0.63$, $p > .50$) (Appendix FF.6).

Maximum Phonation Time Spoken /u/ (MPT /u/)

Examination of the measure MPT of spoken /u/ indicated that both the assumptions of homogeneity of variance-covariance matrices of the three occasions between males and females and sphericity were met. Therefore, the univariate approach was used to examine MPT of spoken /u/. The analysis determined that a main effect for occasion was present for the dependent variable MPT of spoken /i/.

There was no difference between males and females of the variable MPT of spoken /u/ ($F_{1,26} = 2.70$ $p > .10$). There was a significant difference over testing occasions ($F_{2,52} = 4.59$ $p < .02$). The value of eta squared indicated that 15% of the variability in MPT of spoken /u/, pooled over gender, was aligned with testing occasion (repeated measures). The power of the test of the occasion effect was 0.75 which indicated that the alignment is due to slightly more than chance. From the tests of independent trend components, only a significant upward linear trend ($F_{1,26} = 7.58$, $p < .01$) over the three testing occasions was found. This reflects that there was a dramatic training effect over time. Finally, there was no interaction between gender and testing occasion ($F_{2,52} < 1$, $p > .95$) (Appendix FF.7).

Sung Phonation

Musical Frequency Range of Phonation - High (MFRPH)

Examination of the measure MFRPH indicated that both the assumptions of homogeneity of variance-covariance matrices of the three occasions between males and females and sphericity were met. Therefore, the univariate approach was used to examine MFRPH. The analysis determined that the main effect of gender was present for the dependent variable MFRPH.

Females scored significantly higher (nearly doubling) than males on the variable MFRPH ($F_{1,26} = 114.36$, $p < .001$). The value of eta squared indicated that 81% of the variability in MFRPH, pooled over testing occasions, was aligned with gender. The power of the test of the gender effect was maximized (1.0). There was no difference over testing occasion ($F_{2,52} = 0.63$, $p > .35$). Finally, there was no interaction between gender and testing occasion ($F_{2,52} = 0.63$, $p > .50$). This pattern suggests a consistent 2:1 difference (females exceeding males) over the entire training program (Appendix GG.1).

Musical Frequency Range of Phonation - Low (MFRPL)

Examination of the measure MFRPL indicated that neither the assumption of homogeneity of variance-covariance matrices over the three occasions between males and females, nor the sphericity assumption was met. Therefore, the multivariate approach was used to examine MFRPL. The analysis determined that a main effect for gender was present for the dependent variable MFRPL.

Females scored significantly higher (nearly doubled) than males on the variable MFRPL ($F_{1,26} = 158.08$, $p < .001$). The value of eta squared indicated that 85% of the variability in MFRPL, pooled over testing occasions, was aligned with gender. The power of the test of the gender effect was maximized, 1.0. Wilks' Lambda ($\Lambda = 0.88$) indicated that there was no difference over testing occasion ($F_{2,25} = 1.59$, $p > .20$). Finally, there was no interaction between gender and testing occasion ($\Lambda = 0.90$, $F_{2,25} = 1.35$, $p > .25$). This pattern suggests a consistent 2 to 1 advantage for females over males throughout the training program (Appendix GG.2).

Musical Frequency Range of Phonation - Semitones (MFRPS)

Examination of the measure MFRPS indicated that both the assumptions of homogeneity of variance-covariance matrices of the three occasions between males and females and sphericity were met. Therefore, the univariate approach was used to examine MFRPS. The analysis determined that no main or interaction effects were present for the dependent variable MFRPS.

There was no difference between males and females of the variable MFRPS ($F_{1,26} = 0.89$, $p > .35$), and no difference over testing occasion was found ($F_{2,52} = 2.67$, $p > .05$). Finally, there was no interaction between gender and testing occasion ($F_{2,52} = 1.00$, $p > .35$) (Appendix GG.3).

Maximum Phonation Time Sung /ɑ/ (MPT /ɑ/)

Examination of the measure MPT of sung /ɑ/ indicated that the assumption of homogeneity of variance-covariance matrices over the three occasions between males and females was met; however, the sphericity assumption was not met. Therefore, the multivariate approach was used to examine MPT of sung /ɑ/. The analysis determined that a main effect for occasion was present for the dependent variable MPT of sung/ɑ/.

There was no difference between males and females of the variable MPT of sung /ɑ/ ($F_{1,26} < 1$, $p > .30$). There was a significant difference over testing occasion ($\Lambda = 0.70$, $F_{2,25} = 5.29$, $p < .02$). The value of eta squared indicated that 30% of the variability in MPT of sung /ɑ/, pooled over gender, was aligned with testing occasion (repeated measures). The power of the test of the occasion effect was 0.78 which indicated that the alignment was most likely due to more than chance. From the tests of the independent trend components, only a significant increasing linear trend ($F_{1,26} = 6.39$, $p < .01$) over the three testing occasions was found. This reflects that there was a dramatic training effect over time. Finally, there was a significant interaction between gender and testing occasion ($\Lambda = 0.75$, $F_{2,25} = 4.03$, $p < .05$). The nature of the interaction is ordinal (Lubin, 1962) with the difference (males scoring higher than females) diminishing over the three occasions to practically a non-existent level on the third occasion (Appendix GG.4).

Maximum Phonation Time Sung /i/ (MPT /i/)

Examination of the measure MPT of sung /i/ indicated that both the assumptions of homogeneity of variance-covariance matrices over the three occasions between males and females and sphericity were met. Therefore, the univariate approach was used to examine MPT of sung /i/. The analysis

determined that the main effect of occasion was present for the dependent variable MPT of sung/i/.

There was no difference between males and females of the variable MPT of sung /i/ ($F_{1,26} = 0.03$ $p > .85$). There was a significant difference over testing occasion ($F_{2,52} = 8.27$, $p < .01$). The value of eta squared indicated that 24% of the variability in MPT of sung /i/, pooled over gender, was aligned with testing occasion (repeated measures). The power of the test of the occasion effect was nearly at maximum strength, 0.95. From the tests of independent trend components, only a significant increasing linear trend ($F_{1,26} = 13.17$, $p < .001$) over the three testing occasions was found. This reflects that there was a dramatic training effect over time. Finally, there was no interaction between gender and testing occasion ($F_{2,52} < 1$, $p > .65$) (Appendix GG.5).

Maximum Phonation Time Sung /u/ (MPT /u/)

Examination of the measure MPT of sung /u/ indicated that both the assumptions of homogeneity of variance-covariance matrices over the three occasions between males and females and sphericity were met. Therefore, the univariate approach was used to examine MPT of sung /u/. The analysis determined that a main effect for occasion was present for the dependent variable MPT of sung/u/.

There was no difference between males and females of the variable MPT of sung /u/ ($F_{1,26} < 1$, $p > .90$). There was a significant difference over testing occasion ($F_{2,52} = 9.96$, $p < .001$). The value of eta squared indicated that 27% of the variability in MPT of sung /u/, pooled over gender, was aligned with testing occasion (repeated measures). The power of the test of the occasion effect was nearly maximized at 0.97. From the tests of independent trend components, only a significant upward linear trend ($F_{1,26} = 16.67$, $p < .001$) over the three testing

occasions was found. This reflects that there was a dramatic training effect over time. Finally, there was no interaction between gender and testing occasion ($F_{2,52} = 1.70$, $p > .15$) (Appendix GG.6).

Voiceless-to-Voiced Ratio

Maximum /s/

Examination of the measure maximum /s/ indicated that both the assumptions of homogeneity of variance-covariance matrices of the three occasions between males and females and sphericity were met. Therefore, the univariate approach was used to examine maximum /s/. The analysis determined that a main effect for occasion was present for the dependent variable maximum /s/.

There was no difference between males and females of the variable maximum /s/ ($F_{1,26} < 1$, $p > .75$). There was a significant difference over testing occasion ($F_{2,52} = 7.35$, $p < .005$). The value of eta squared indicated that 22% of the variability in maximum /s/ was aligned with testing occasion (the repeated measures). The power of the test for the occasion effect was nearly at its maximum, 0.92. From the tests of independent trend components, only a significant upward linear trend ($F_{1,26} = 12.38$, $p < .001$) over the three testing occasions was found. This reflects that there was a dramatic training effect over time. Finally, there was no interaction between gender and testing occasion ($F_{2,52} < 1$, $p > .70$) (Appendix HH.1).

Maximum phonation /z/

Examination of the measure maximum phonation of /z/ indicated that both the assumptions of homogeneity of variance-covariance matrices of the three occasions between males and females and sphericity were met. Therefore, the

univariate approach was used to examine maximum phonation of /z/. The analysis determined that a main effect for occasion was present for the dependent variable maximum /z/.

There was no difference between males and females of the variable maximum phonation of /z/ ($F_{1,26} < 1$, $p > .85$). There was a significant difference over testing occasion ($F_{2,52} = 12.87$, $p < .001$). The value of eta squared indicated that 33% of the variability in maximum phonation of /z/ was aligned with testing occasion (the repeated measures). The power of the test was nearly at its maximum, 0.99. From the tests of independent trend components a significant upward linear trend ($F_{1,26} = 26.82$, $p < .001$) over the three testing occasions was found. This indicates that the maximum phonation of /z/ steadily increased from occasion one to occasion three, and this reflects a dramatic training effect of the program over time. Finally, there was no interaction between gender and testing occasion ($F_{2,52} < 1$, $p > .55$) (Appendix HH.2).

S/Z Ratio

Examination of the measure s/z ratio indicated that the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was not met; however, the sphericity assumption was met. Therefore, the multivariate approaches were used to examine the s/z ratio. The analysis determined that no main or interaction effect was present for the dependent variable s/z ratio.

There was no difference between males and females of the variable s/z ratio ($F_{1,26} < 1$, $p > .80$). There was no difference over testing occasion ($\Lambda = 0.98$, $F_{2,25} = 0.23$, $p > .75$) approaches. Finally, there was no interaction between gender and testing occasion using the multivariate test ($\Lambda = 0.91$, $F_{2,25} = 1.12$, p

> .30). This reflects that there was no dramatic training effect over time (Appendix HH.3).

Respiratory Measures

Forced Vital Capacity (FVC)

Examination of the measure FVC indicated that both the assumptions of homogeneity of variance-covariance matrices of the three occasions between males and females and sphericity were met. Therefore, the univariate approach was used to examine FVC. The analysis determined that a main effect for occasion was present for the dependent variable FVC.

There was no difference between males and females of the variable FVC ($F_{1,26} < 1$, $p > .80$). There was a significant difference over testing occasion ($F_{2,52} = 8.30$, $p < .01$). The value of eta squared indicated that 24% of the variability in FVC was aligned with testing occasion (the repeated measures). The power of the test of the occasion effect was nearly maximized, 0.95. From the tests of independent trend components, only a significant positive quadratic trend ($F_{1,26} = 23.76$, $p < .001$) over the three testing occasions was found. This indicates that FVC decreased from occasion one to occasion two, and then increased from occasion two to occasion three. This reflects that there was a dramatic training effect over time. Finally, there was no interaction between gender and testing occasion ($F_{2,52} = 1.77$, $p > .15$) (Appendix II.1).

Forced Expiratory Volume (FEV 1.0)

Examination of the measure FEV 1.0 indicated that both the assumptions of homogeneity of variance-covariance matrices of the three occasions between males and females and sphericity were met. Therefore, the univariate approach

was used to examine FEV 1.0. The analysis determined that a main effect of occasion was present for the dependent variable FEV 1.0.

There was no difference between males and females of the variable FEV 1.0 ($F_{1,26} = 0.52$ $p > .45$). There was a significant difference over testing occasion ($F_{2,52} = 5.98$, $p < .01$). The value of eta squared indicated that 18% of the variability in FEV 1.0 was aligned with testing occasion (the repeated measures). The power of the test of the occasion effect was 0.86 which indicated that the alignment was due to more than chance. From the tests of independent trend components, both a significant downward linear trend ($F_{1,26} = 5.93$, $p < .05$) and a significant positive quadratic trend ($F_{1,26} = 6.08$, $p < .05$) over the three testing occasions were found. The two trends are of nearly equal strength (0.18 and 0.19 respectively) and reflect a dramatic training effect over time. Finally, there was no interaction between gender and testing occasion ($F_{2,52} = 1.38$, $p > .25$) (Appendix II.2).

Forced Expiratory Flow (FEF 25%-75%)

Examination of the measure FEF 25% - 75% indicated that neither the assumption of homogeneity of variance-covariance matrices over the three occasions between males and females, nor the sphericity assumption was met. Therefore, the multivariate approach was used to examine FEF 25% - 75%. The analysis determined that a main effect for occasion was present for the dependent variable FEF 25% - 75%.

There was no difference between males and females of the variable FEF 25% - 75% ($F_{1,26} < 1$, $p > .60$). There was no difference over testing occasion ($\Lambda = 0.78$, $F_{2,25} = 3.34$, $p > .05$). Finally, there was no interaction between gender and testing occasion ($\Lambda = 0.78$, $F_{2,25} = 0.11$ $p > .85$). This reflects that there was no dramatic training effect over time (Appendix II.3).

Mean Flow Rate (MFR)

In examining the measure MFR, the assumption of homogeneity of variance-covariance matrices of the three occasions between males and females was met; however, the sphericity assumption was not met. Therefore, the multivariate approach was used to examine MFR. Analysis determined that the main effect of occasion was present for the dependent variable FEF 25% - 75%.

There was no difference between males and females of the variable MFR ($F_{1,26} = 0.63$ $p > .40$). There was a significant difference over testing occasion ($\Lambda = 0.71$, $F_{2,25} = 4.93$, $p < .02$). The value of eta squared indicated that 28% of the variability in MFR, pooled over gender, was aligned with testing occasion (the repeated measures). The power of the test of the occasion effect was 0.76 which indicated that the alignment was due to only slightly better than chance. From the tests of independent trend components, a significant downward linear trend ($F_{1,26} = 7.25$, $p < .02$) and a significant positive quadratic trend ($F_{1,26} = 6.44$, $p < .05$) over the three testing occasions were found. This reflects that there was a dramatic training effect over time. Finally, there was no interaction between gender and testing occasion ($\Lambda = 0.90$, $F_{2,25} = 1.24$ $p > .30$) (Appendix II.4).

Comparison of Observed Data with Norms

Within each of the three domains--acoustic, phonatory, and respiratory--the central tendency of each measure from the observed data was compared against the corresponding norm cited by authoritative sources (Baken 1987; Kay Elemetrics-Deliyski 1993; Sataloff 1990; and Hirano 1981). The acoustic measures will be discussed first. Ninety-nine percent confidence was *simultaneously* spread over the entire set of 18 acoustic measures to protect against compounding type I errors as each of the *successive* measures was examined. The 20 phonatory and respiratory measures subsequently will be discussed together and are treated in a

similar fashion. By using a set of simultaneous confidence intervals the following decisions about each measure were made: (1) the value of a norm was corroborated if it fell within the respective confidence interval; (2) a directional departure from the value of the norm was established when it fell outside the respective confidence interval; (3) the overall width of a confidence interval was inversely related to the power of the decision regarding the displacement of the obtained result from the value of the norm cited in the literature and conventionally employed in laboratories. Data were combined over the three occasions and used to execute this procedure. (Consult appendix JJ for the corresponding means and standard deviations).

Acoustic Measures of Spoken /ɑ/

Fundamental Frequency/Perturbation Measures

Male F_o

The simultaneous 99% confidence interval for the mean ranged from 93.88 Hz to 152.81 Hz and contained the norm of 119.5 Hz. This sample corroborated the established norm.

Female F_o

The simultaneous 99% confidence interval for the mean ranged from 189.30 Hz to 224.31 82 and contained the norm of 224.3 Hz. (It should be noted that had a separate interval been constructed in which 99% confidence was exclusively invested, it would have been of shorter width and would have led to not corroborating the norm).

Combined Jita

The simultaneous 99% confidence interval for the mean ranged from 34.47 us to 70.57 us and did not contain the norm of 83.2 us. This sample exhibited a substantially *lower* mean; in fact, the upper limit of the confidence interval for the mean was more than 10 points lower than the norm. The relative power of the decision was 85%.

Combined RAP

The simultaneous 99% confidence interval for the mean ranged from 0.35% to 0.65% and did not contain the norm of 0.68%. This sample exhibited a *lower* mean; however, the relative power of this decision was only 62%.

Combined PPQ

The simultaneous 99% confidence interval for the mean ranged from 0.34% to 0.64% and did not contain the norm of 0.84%. This sample exhibited a substantially *lower* mean; in fact, the upper limit of the confidence interval for the mean was 20 points lower than the norm. This translates into maximum available power (99%).

Combined sPPQ

The simultaneous 99% confidence interval for the mean ranged from 0.55% to 0.81% and did not contain the norm of 1.02%. This sample exhibited a *lower* mean. The relative power of the decision was at maximum strength (99%).

Combined Jitt

The simultaneous 99% confidence interval for the mean ranged from 0.58% to 1.08% and contained the norm of 1.04%. This sample corroborated the established norm.

Combined vFo

The simultaneous 99% confidence interval for the mean ranged from 0.87% to 1.29%. The interval contained the norm of 1.1%, and thus this sample corroborates the currently employed norm.

In summary, the norms for 4 out of 8 fundamental frequency measures can be disputed. The strengths of the decisions can be ranked in terms of relative power associated with each: sPPQ (99%), PPQ (99%), Jita (85%), and RAP (68%).

Amplitude Perturbation Measures

Combined vAm

The simultaneous 99% confidence interval for the mean ranged from 9.85% to 13.35% and did not contain the norm of 8.2%. The sample displayed a substantially *higher* mean. The relative power of the decision was nearly at maximum strength (97%).

Combined ShdB

The simultaneous 99% confidence interval for the mean ranged from 0.21 dB to 0.39 dB and trapped the norm of 0.35 dB. This sample corroborated the established norm.

Combined Shim

The simultaneous 99% confidence interval for the mean ranged from 2.45% to 4.43% and contained the norm of 3.81%. This sample corroborated the established norm.

Combined APQ

The simultaneous 99% confidence interval for the mean ranged from 2.07% to 3.63% and trapped the norm of 3.07%. This sample corroborated the established norm.

Combined sAPQ

The simultaneous 99% confidence interval for the mean ranged from 4.36% to 6.40% and contained the norm of 4.23%. This sample corroborated the established norm.

In summary, norms for 1 out of 5 combined Amplitude Measures can be disputed (vAm 97%).

Noise Related Measures

Combined NHR

The simultaneous 99% confidence interval for the means ranged from 0.117 to 0.142 and did not contain the norm of 0.19. This sample exhibited a *lower* mean than the reported norm, and the relative power of the decision was at maximum strength (99%).

Combined VTI

The simultaneous 99% confidence interval for the mean ranged from 0.042 to 0.058 and did not contain the norm of 0.061; however the relative power of the decision was only 56%.

Combined SPI

The simultaneous 99% confidence interval for the mean ranged from 7.72 to 14.90 and trapped the norm of 14.12. Hence, this sample corroborated the norm.

In summary, the norms for 2 out of 3 additional measures can be disputed. The strength of the decision associated with each measure can be ranked in terms of the relative power as follows: NHR (99%), and VTI (56%).

Tremor Related Measures

Combined FTRI

The simultaneous 99% confidence interval of the mean ranged from 0.27% to 0.43% and did not contain the norm of 0.95%. This sample exhibited substantially *lower* mean than the reported norm. The power of the decision was at maximum strength (99%).

Combined ATRI

The simultaneous 99% confidence interval for the mean ranged from 3.88% to 5.48% and contained the norm of 4.37%. This sample corroborated the established norm.

In summary the norms for one out of two tremor-related measures can be disputed (FTRI 99%).

Fftr & Fatr

Norms do not exist for either Fftr or Fatr measures since each is indexed relative to the individual subject's actual pitch or fundamental frequency. Therefore, it is inappropriate for the apparatus (CSL) to display norms established by pooling over several subjects. However, the precedent for incorporating descriptive information for these measures has been established (Baken 1987; Sataloff 1990). The means and standard deviations are displayed separately for males and females since the measures are directly related to the relative fundamental frequency. The data are as follows:

TABLE 7

Fftr and Fatr Measures Spoken /ɑ/

	Males (n = 13)	Females (n = 15)
Fftr	$\bar{X}$ = 3.44 (SD = .706)	$\bar{X}$ = 3.57 (SD = 1.64)
Fatr	$\bar{X}$ = 3.24 (SD = .744)	$\bar{X}$ = 3.31 (SD = .790)

When simultaneous 99% confidence intervals are constructed about the mean for each of these measures the following results, found in Table 8 below, are obtained.

Table 8

Fftr and Fatr Simultaneous 99% Confidence Intervals Spoken /ɑ/

	Males (n = 13)	Females (n = 15)
Fftr	2.66 < u< 4.24	1.85 < u < 5.29
Fatr	2.41 < u < 4.07	2.49 < u < 4.13

The set of 18 Acoustic Measures for spoken /ɑ/

The strength of the decisions regarding the overall set of 18 acoustic measures for spoken /a/ can be ranked by relative power associated with each: NHR (99%), sPPQ (99%), FTRI (99%), PPQ (99%), vAm (97%), Jita (85%), RAP (68%), and VTI (56%). Hence, these data lead to disputing the current values of 8 of the 18 acoustic norms.

Acoustic Measures of Spoken /i/

Fundamental Frequency/Perturbation Measures

Male F_o

The simultaneous 99% confidence interval for the mean ranged from 93.64 Hz to 155.40 Hz and contained the norm of 119.5 Hz. This sample corroborated the established norm.

Female F_o

The simultaneous 99% confidence interval for the mean ranged from 194.55 Hz to 228.31 21 and contained the norm of 224.3 Hz. (It should be noted that had a separate interval been constructed in which 99% confidence was

exclusively invested, it would have been of shorter width and would have led to not corroborating the norm).

Combined PPQ

The simultaneous 99% confidence interval for the mean ranged from 0.37% to 0.83% and did not contain the norm of 0.84%. This sample exhibited a *lower* mean, however the relative power of the decision was only 52%.

Combined sPPQ

The simultaneous 99% confidence interval for the mean ranged from 0.54% to 0.96% and did not contain the norm of 1.02%. This sample exhibited a *lower* mean, however the relative power of the decision was only 65%.

Combined Jita

The simultaneous 99% confidence interval for the mean ranged from 40.70 us to 84.26 us and contained the norm of 83.2 us. This sample corroborated the established norm. (It should be noted that had a separate interval been constructed in which 99% confidence was exclusively invested, it would have been of shorter width and would have led to not corroborating the norm).

Combined Jitt

The simultaneous 99% confidence interval for the mean ranged from 0.63% to 1.43% and trapped the norm of 1.04%. This sample corroborated the established norm.

Combined RAP

The simultaneous 99% confidence interval for the mean ranged from 0.37% to 0.85% and contained the norm of 0.68%. This sample corroborated the established norm.

Combined vFo

The simultaneous 99% confidence interval for the mean ranged from 0.95% to 1.45%. The interval contained the norm of 1.1%; thus, this sample corroborated the currently employed norm.

In summary, the norms for 2 out of 8 fundamental frequency measures can be disputed. The strengths of the decisions can be ranked in terms of relative power associated with each: sPPQ (65%) and PPQ (52%).

Amplitude Perturbation Measures

Combined ShdB

The simultaneous 99% confidence interval for the mean ranged from 0.175 dB to 0.265 dB and did not contain the norm of 0.35 dB. This sample exhibited a *lower* mean than the reported norm. The relative power of the decision was at maximum strength (99%).

Combined Shim

The simultaneous 99% confidence interval for the mean ranged from 2.03% to 3.01% and did not contain the norm of 3.81%. This sample exhibited a *lower* mean than the reported norm. The relative power of the decision was at maximum strength (99%).

Combined APQ

The simultaneous 99% confidence interval for the mean ranged from 1.54% to 2.34% and did not contain the norm of 3.07%. This sample exhibited a substantially *lower* mean than the reported norm. The relative power of the decision was at maximum strength (99%).

Combined sAPQ

The simultaneous 99% confidence interval for the mean ranged from 2.85% to 4.79% and contained the norm of 4.23%. This sample corroborated the established norm.

Combined vAm

The simultaneous 99% confidence interval for the mean ranged from 6.95% to 10.79% and trapped the norm of 8.2%. This sample corroborated the established norm.

In summary, norms for 3 out of 5 combined Amplitude Measures can be disputed. The strength of the decision associated with each measure can be ranked in terms of the relative power as follows: ShdB (99%), APQ (99%), and Shim (99%).

Noise Related Measures

Combined NHR

The simultaneous 99% confidence interval for the means ranged from 0.108 to 0.132 and did not contain the norm of 0.19. This sample exhibited a *lower* mean than the reported norm, and the relative power of the decision was at maximum strength (99%).

Combined SPI

The simultaneous 99% confidence interval for the mean ranged from 4.65 to 10.85 and did not contain the norm of 14.12. This sample exhibited a substantially *lower* mean than the reported norm, the relative power of the decision was at maximum strength (99%).

Combined VTI

The simultaneous 99% confidence interval for the mean ranged from 0.048 to 0.072 and trapped the norm of 0.061. Hence, this sample corroborated the norm.

In summary, the norms for 2 out of 3 additional measures can be disputed. The strength of the decision associated with each measure can be ranked in terms of the relative power as follows: NHR (99%), and SPI (99%).

Tremor Related Measures

Combined FTRI

The simultaneous 99% confidence interval of the mean ranged from 0.26% to 0.40% and did not contain the norm of 0.95%. This sample exhibited substantially *lower* mean than the reported norm. The power of the decision was at maximum strength (99%).

Combined ATRI

The simultaneous 99% confidence interval for the mean ranged from 2.71% to 4.61% and contained the norm of 4.37%. This sample corroborated the established norm.

In summary the norms for one out of two tremor-related measures can be disputed (FTRI 99%).

Fftr & Fatr

Norms do not exist for either Fftr or Fatr measures since each is indexed relative to the individual subject's actual pitch or fundamental frequency. The means and standard deviations are displayed separately for males and females since the measures are directly related to the relative fundamental frequency. The data are as follows:

TABLE 9

Fftr and Fatr Measures Spoken /i/

	Males (n = 13)	Females (n = 15)
Fftr	$\bar{X}$ = 4.61 (SD = 1.88)	$\bar{X}$ = 3.61 (SD = 1.36)
Fatr	$\bar{X}$ = 3.17 (SD = .704)	$\bar{X}$ = 3.44 (SD = .760)

When simultaneous 99% confidence intervals are constructed about the mean for each of these measures, the following results, found in Table 10 below, are obtained.

Table 10

Fftr and Fatr Simultaneous 99% Confidence Intervals Spoken /i/

	Males (n = 13)	Females (n = 15)
Fftr	2.50 < u< 6.72	2.20 < u < 5.04
Fatr	2.83 < u < 3.96	2.66 < u < 4.24

The set of 18 Acoustic Measures for spoken /i/

The strength of the decisions regarding the overall set of 18 acoustic measures for spoken /i/ can be ranked by relative power associated with each: FTRI (99%), NHR (99%), ShdB (99%), APQ (99%), Shim (99%), SPI (99%), sPPQ (65%), PPQ (52%). Hence, these data lead to disputing the current values of 8 of the 18 acoustic norms.

Acoustic Measures of Spoken /u/

Fundamental Frequency/Perturbation Measures

Male F_o

The simultaneous 99% confidence interval for the mean ranged from 93.54 Hz to 161.10 Hz and contained the norm of 119.5 Hz. This sample corroborated the established norm.

Female F_o

The simultaneous 99% confidence interval for the mean ranged from 197.83 Hz to 229.37 and contained the norm of 224.3 Hz. (It should be noted that had a separate interval been constructed in which 99% confidence was exclusively invested, it would have been of shorter width and would have led to not corroborating the norm).

Combined Jita

The simultaneous 99% confidence interval for the mean ranged from 43.64 to 64.02 and did not contain the norm of 83.2. This sample exhibited a significantly *lower* mean than the reported norm. The relative power of the decision was at maximum strength (99%).

Combined PPQ

The simultaneous 99% confidence interval for the mean ranged from 0.41% to 0.67% and did not contain the norm of 0.84%. This sample exhibited a *lower* mean, and the relative power of the decision was at maximum strength (99%).

Combined sPPQ

The simultaneous 99% confidence interval for the mean ranged from 0.55% to 0.79% and did not contain the norm of 1.02%. This sample exhibited a *lower* mean. The relative power of the decision was at maximum strength (99%).

Combined Jitt

The simultaneous 99% confidence interval for the mean ranged from 0.68% to 1.16% and trapped the norm of 1.04%. This sample corroborated the established norm.

Combined RAP

The simultaneous 99% confidence interval for the mean ranged from 0.40% to 0.70% and contained the norm of 0.68%. This sample corroborated the established norm.

Combined vFo

The simultaneous 99% confidence interval for the mean ranged from 0.88% to 1.22%. The interval contained the norm of 1.1%; thus, this sample corroborated the currently employed norm.

In summary, the norms for 3 out of 8 fundamental frequency measures can be disputed. The strengths of the decisions can be ranked in terms of relative power associated with each: sPPQ (99%), Jita (99%), and PPQ (99%).

Amplitude Measures

Combined ShdB

The simultaneous 99% confidence interval for the mean ranged from 0.108 dB to 0.172 dB and did not contain the norm of 0.35 dB. This sample exhibited a *lower* mean than the reported norm. The relative power of the decision was at maximum strength (99%).

Combined Shim

The simultaneous 99% confidence interval for the mean ranged from 1.25% to 1.93% and did not contain the norm of 3.81%. This sample exhibited a *lower* mean than the reported norm. The relative power of the decision was at maximum strength (99%).

Combined APQ

The simultaneous 99% confidence interval for the mean ranged from 0.98% to 1.70% and did not contain the norm of 3.07%. This sample exhibited a substantially *lower* mean than the reported norm. The relative power of the decision was at maximum strength (99%).

Combined sAPQ

The simultaneous 99% confidence interval for the mean ranged from 2.24% to 4.28% and contained the norm of 4.23%. This sample corroborated the established norm.

Combined vAm

The simultaneous 99% confidence interval for the mean ranged from 6.12% to 10.26% and trapped the norm of 8.2%. This sample corroborated the established norm.

In summary, norms for 3 out of 5 combined Amplitude Measures can be disputed. The strength of the decision associated with each measure can be ranked in terms of the relative power as follows: ShdB (99%), Shim (99%), and APQ (99%).

Noise Related Measures

Combined NHR

The simultaneous 99% confidence interval for the means ranged from 0.098 to 0.122 and did not contain the norm of 0.19. This sample exhibited a *lower* mean than the reported norm, and the relative power of the decision was at maximum strength (99%).

Combined VTI

The simultaneous 99% confidence interval for the mean ranged from 0.025 to 0.035 and did not contain the norm of 0.061. This sample exhibited a *lower* mean than the reported norm, and the relative power of the decision was at maximum strength (99%).

Combined SPI

The simultaneous 99% confidence interval for the mean ranged from 31.99 to 63.07 and did not contain the norm of 14.12. The relative power of the decision was at maximum strength (99%).

In summary, the norms for 3 out of 3 additional measures can be disputed. The strength of the decision associated with each measure can be ranked in terms of the relative power as follows: NHR (99%), VTI (99%), and SPI (99%).

Tremor Related Measures

Combined FTRI

The simultaneous 99% confidence interval of the mean ranged from 0.233% to 0.387% and did not contain the norm of 0.95%. This sample exhibited substantially *lower* mean than the reported norm. The power of the decision was at maximum strength (99%).

Combined ATRI

The simultaneous 99% confidence interval for the mean ranged from 2.43% to 4.39% and contained the norm of 4.37%. This sample corroborated the established norm.

In summary the norms for one out of two tremor-related measures can be disputed (FTRI 99%).

Fftr & Fatr

Norms do not exist for either Fftr or Fatr measures since each is indexed relative to the individual subject's actual pitch or fundamental frequency. The means and standard deviations are displayed separately for males and females since the measures are directly related to the relative fundamental frequency. The data are as follows:

TABLE 11

Fftr and Fatr Measures Spoken /u/

	Males (n = 13)	Females (n = 15)
Fftr	$\bar{X}$ = 4.12 (SD = 2.04)	$\bar{X}$ = 3.43 (SD = .931)
Fatr	$\bar{X}$ = 3.08 (SD = .612)	$\bar{X}$ = 3.12 (SD = .546)

When simultaneous 99% confidence intervals are constructed about the mean for each of these measures, the following results, found in table 12 below, are obtained.

Table 12

Fftr and Fatr Simultaneous 99% Confidence Intervals Spoken /u/

	Males (n = 13)	Females (n = 15)
Fftr	1.84 < u< 6.42	2.46 < u < 4.40
Fatr	2.39 < u < 3.77	2.53 < u < 3.69

The set of 18 Acoustic Measures for spoken /u/

The strength of the decisions regarding the overall set of 18 acoustic measures for spoken /u/ can be ranked by relative power associated with each: FTRI (99%), NHR (99%), VTI (99%), ShdB (99%), Shim (99%), APQ (99%), sPPQ

(99%), Jita (99%), PPQ (99%), and SPI (99%). Hence, these data lead to disputing the current values of 10 of the 18 acoustic norms.

Acoustic Measures of Sung /ɑ/

Fundamental Frequency/Perturbation Measures

Male F_o

The simultaneous 99% confidence interval for the mean ranged from 133.76 Hz to 209.61 Hz and did not contain the norm of 119.5 Hz. Not only did the males in this sample exhibit a substantially *higher* mean, the relative power of this decision was 69%.

Female F_o

The simultaneous 99% confidence interval for the mean ranged from 285.39 Hz to 504.31 Hz and did not contain the norm of 224.3 Hz. Again the females in this sample displayed substantially *higher* means. The relative power of this decision was 77%.

Combined Jita

The simultaneous 99% confidence interval for the mean ranged from 32.85 us to 49.99 us and did not contain the norm of 83.2 us. This sample exhibited a substantially *lower* mean; in fact, the upper limit of the confidence interval for the mean was more than 30 points lower than the norm. This translates into maximum available power (99%) despite the sample size n = 28.

Combined RAP

The simultaneous 99% confidence interval for the mean ranged from 0.37% to 0.63% and did not contain the norm of 0.68%. This sample exhibited a substantially *lower* mean; the relative power of this decision was 68%.

Combined PPQ

The simultaneous 99% confidence interval for the mean ranged from 0.38% to 0.64% and did not contain the norm of 0.84%. This sample exhibited a substantially *lower* mean; in fact, the upper limit of the confidence interval for the mean was 20 points lower than the norm. This again translates into maximum available power (99%).

Combined vFo

The simultaneous 99% confidence interval for the mean ranged from 1.37% to 2.45% and did not contain the norm of 1.1%. This sample exhibited a substantially *higher* mean than the norm. The relative power of this decision was 75%.

Combined Jitt

The simultaneous 99% confidence interval for the mean ranged from 0.70% to 1.08%. The interval contained the norm of 1.04%; thus, this sample corroborated the currently employed norm.

Combined sPPQ

The simultaneous 99% confidence interval for the mean ranged from 0.80% to 2.04%. The interval contained the norm of 1.02%; hence, this sample corroborated the currently employed norm.

In summary, the norms for 6 out of 8 fundamental frequency measures can be disputed. The strengths of the decisions can be ranked in terms of relative power associated with each: Jita (99%), PPQ (99%), vFo (75%), and RAP (68%). Finally, the female F_O was stronger than the male F_O(77% - 69% respectively).

Amplitude Perturbation Measures

Combined sAPQ

The simultaneous 99% confidence interval for the mean ranged from 6.20% to 9.26% and did not contain the norm of 4.23%. This sample displayed a substantially *higher* mean. The disparity between the sample mean and the norm more than exceeded the width of the interval, hence the power of the decision was maximized (99%) .

Combined vAm

The simultaneous 99% confidence interval for the mean ranged from 11.19% to 16.19% and did not contain the norm of 8.2%. Again the sample displayed a substantially *higher* mean. The disparity between the sample mean and the norm more than exceeded the width of the interval, and so the power of this decision was also maximized (99%).

Combined ShdB

The simultaneous 99% confidence interval for the mean ranged from 0.22 dB to 0.40 dB and trapped the norm of 0.35 dB. This sample corroborated the established norm.

Combined Shim

The simultaneous 99% confidence interval for the mean ranged from 2.56% to 4.50% and contained the norm of 3.81%. This sample corroborated the established norm.

Combined APQ

The simultaneous 99% confidence interval for the mean ranged from 2.54% to 4.78% and trapped the norm of 3.07%. This sample corroborated the established norm.

In summary, norms for 2 out of 5 combined Amplitude Perturbation Measures can be disputed. The strength of the decision associated with each measure can be ranked in terms of the relative power as follows: sAPQ (99%), and vAm (99%).

Noise Related Measures

Combined NHR

The simultaneous 99% confidence interval for the means ranged from 0.08 to 0.18 and did not contain the norm of 0.19. This sample exhibited a *higher* mean than the reported norm; however, the relative power of the decision was only 63%.

Combined SPI

The simultaneous 99% confidence interval for the mean ranged from 7.06 to 14.72 and contained the norm of 14.12; hence, this sample corroborated the norm. (It should be noted that had a separate interval been constructed in which 99% confidence was exclusively invested, it would have been of shorter width and led to not corroborating the norm).

Combined VTI

The simultaneous 99% confidence interval for the mean ranged from 0.035 to 0.084 and trapped the norm of 0.061. Hence, this sample corroborated the norm.

In summary, the norms for 1 out of 3 (NHR) Noise Related Measures can be disputed.

Tremor Related Measures

Combined ATRI

The simultaneous 99% confidence interval for the mean ranged from 5.68% to 8.91% and did not contain the norm of 4.37%. This sample exhibited a substantially *higher* mean; the relative power of this decision was 90%.

Combined FTRI

The simultaneous 99% confidence interval of the mean ranged from 0.73% to 1.93% and trapped the norm of 0.95%. This sample thus corroborated the norm.

In summary the norms for one out of two tremor-related measures can be disputed.

Fftr & Fatr

Norms do not exist for either Fftr or Fatr measures since each is indexed relative to the individual subject's actual pitch or fundamental frequency. Therefore, it is inappropriate for the apparatus (CSL) to display norms established by pooling over several subjects. However, the precedent for incorporating descriptive information for these measures has been established (Baken 1987; Sataloff 1990). The means and standard deviations are displayed separately for

males and females since the measures are directly related to the relative fundamental frequency. The data are as follows:

TABLE 13

Fftr and Fatr Measures Sung /ɑ/

	Males (n = 13)	Females (n = 15)
Fftr	$\bar{X}$ = 4.74 (SD = .387)	$\bar{X}$ = 4.89 (SD = .511)
Fatr	$\bar{X}$ = 4.84 (SD = .397)	$\bar{X}$ = 4.88 (SD = .469)

When simultaneous 99% confidence intervals are constructed about the mean for each of these measures the following results, found in Table 14 below, are obtained.

Table 14

Fftr and Fatr Simultaneous 99% Confidence Intervals Sung /ɑ/

	Males (n = 13)	Females (n = 15)
Fftr	4.31 < u < 5.18	4.35 < u < 5.42
Fatr	4.40 < u < 5.28	4.40 < u < 5.38

The set of 18 Acoustic Measures for sung /ɑ/

The strength of the decisions regarding the overall set of 18 acoustic measures for sung /ɑ/ can be ranked by relative power associated with each: Jita (99%), PPQ (99%), sAPQ (99%), vAm (99%), ATRI (90%), female F_0 (77%), vFo (75%), male F_0 (69%), RAP (68%), and NHR (63%). Hence, these data lead to disputing the current values of 10 of the 18 acoustic norms.

Acoustic Measures of Sung /i/

Fundamental Frequency/Perturbation Measures

Male F_o

The simultaneous 99% confidence interval for the mean ranged from 135.40 Hz to 214.02 Hz and did not contain the norm of 119.5 Hz. Not only did the males in this sample exhibit a substantially *higher* mean, the relative power of this decision was 70%.

Female F_o

The simultaneous 99% confidence interval for the mean ranged from 288.96 Hz to 507.88 Hz and did not contain the norm of 224.3 Hz. Again the females in this sample displayed substantially *higher* means. The relative power of this decision was 80%.

Combined Jita

The simultaneous 99% confidence interval for the mean ranged from 14.76 us to 46.96 us and did not contain the norm of 83.2 us. This sample exhibited a substantially *lower* mean; in fact, the upper limit of the confidence interval for the mean was more than 30 points lower than the norm. This translates into maximum available power (99%) despite the sample size n = 28.

Combined PPQ

The simultaneous 99% confidence interval for the mean ranged from 0.40% to 0.70% and did not contain the norm of 0.84%. This sample exhibited a substantially *lower* mean; in fact, the upper limit of the confidence interval for the mean was more than 10 points lower than the norm. The relative power of this decision was 96%.

Combined sPPQ

The simultaneous 99% confidence interval for the mean ranged from 1.65% to 3.67% and did not contain the norm of 1.02%. This sample exhibited a substantially *higher* mean. The relative power of this decision was 81%.

Combined vFo

The simultaneous 99% confidence interval for the mean ranged from 1.45% to 2.43% and did not contain the norm of 1.1%. This sample exhibited a substantially *higher* mean than the norm. The relative power of this decision was 86%.

Combined Jitt

The simultaneous 99% confidence interval for the mean ranged from 0.68% to 1.20%. The interval contained the norm of 1.04%; thus, this sample corroborated the currently employed norm.

Combined RAP

The simultaneous 99% confidence interval for the mean ranged from 0.38% to 0.70%. The interval contained the norm of 0.68; hence, this sample corroborated the currently employed norm.

In summary, the norms for 6 out of 8 Fundamental Frequency Perturbation Measures can be disputed. The strengths of the decisions can be ranked in terms of relative power associated with each: Jita (99%), PPQ (96%), vFo (86%), and sPPQ (81%). Finally, the female F_O was stronger than the male F_O (80% - 70% respectively.

Amplitude Perturbation Measures

Combined ShdB

The simultaneous 99% confidence interval for the mean ranged from 0.16 dB to 0.30 dB and did not contain the norm of 0.35. This sample exhibited a *lower* mean than the reported norm. The relative power of the decision was 85%.

Combined Shim

The simultaneous 99% confidence interval for the mean ranged from 1.82% to 3.34% and did not contain the norm of 3.81. This sample exhibited a *lower* mean than the reported norm. The relative power of the decision was 82%.

Combined sAPQ

The simultaneous 99% confidence interval for the mean ranged from 4.45% to 7.69% and did not contain the norm of 4.23%. This sample displayed a *higher* mean than the reported norm; however, the relative power of the decision was only 57%.

Combined vAm

The simultaneous 99% confidence interval for the mean ranged from 9.02% to 14.34% and did not contain the norm of 8.2%. This sample displayed a *higher*

mean than the reported norm; however, the relative power of the decision was only 65%.

Combined APQ

The simultaneous 99% confidence interval for the mean ranged from 1.60 dB to 3.18 dB and trapped the norm of 3.07 dB. This sample corroborated the established norm.

In summary, norms for 4 out of 5 combined Amplitude Perturbation Measures can be disputed. The strength of the decision associated with each measure can be ranked in terms of the relative power as follows: ShdB (85%), Shim (82%), vAm (65%), and sAPQ (57%).

Noise Related Measures

Combined SPI

The simultaneous 99% confidence interval for the mean ranged from 3.80 to 7.88 and did not contain the norm of 14.12. This sample exhibited a substantially *lower* mean; in fact, the relative power of the decision was at maximum power (99%).

Combined NHR

The simultaneous 99% confidence interval for the mean ranged from 0.065 to 0.195 and contained the norm of 0.19. Hence, this sample corroborated the norm.

Combined VTI

The simultaneous 99% confidence interval for the mean ranged from 0.027 to 0.093 and trapped the norm of 0.061. Hence, this sample corroborated the norm.

In summary, the norms for 1 out of 3 (SPI) Noise Related Measures can be disputed.

Tremor Related Measures

Combined ATRI

The simultaneous 99% confidence interval for the mean ranged from 4.94% to 9.12% and did not contain the norm of 4.37%. This sample exhibited a *higher* mean than the norm; however, the relative power of this decision was 63%.

Combined FTRI

The simultaneous 99% confidence interval of the mean ranged from 0.78% to 1.84% and trapped the norm of 0.95%. This sample thus corroborated the norm.

In summary the norms for one out of two tremor-related measures can be disputed.

Fftr & Fatr

Norms do not exist for either Fftr or Fatr measures since each is indexed relative to the individual subject's actual pitch or fundamental frequency. The means and standard deviations are displayed separately in table 15 below for males and females since the measures are directly related to the relative fundamental frequency. The data are as follows:

TABLE 15

Fftr and Fatr Measures Sung /i/

	Males (n = 13)	Females (n = 15)
Fftr	$\bar{X}$ = 4.75 (SD = .419)	$\bar{X}$ = 4.95 (SD = .518)
Fatr	$\bar{X}$ = 4.76 (SD = .372)	$\bar{X}$ = 4.91 (SD = .549)

When simultaneous 99% confidence intervals are constructed about the mean for each of these measures, the following results, found in Table 16 below, are obtained.

Table 16

Fftr and Fatr Simultaneous 99% Confidence Interval Sung /i/

	Males (n = 13)	Females (n = 15)
Fftr	4.28 < u < 5.22	4.41 < u < 5.49
Fatr	4.35< u < 5.19	4.34 < u < 5.48

The set of 18 Acoustic Measures for sung /i/

The strength of the decisions regarding the overall set of 18 acoustic measures for sung /i/ can be ranked by relative power associated with each: Jita (99%), SPI (99%), PPQ (96%), vFo (86%), ShdB (85%), Shim (82%), sPPQ (81%),

female F_0 (80%), male F_0 (70%), vAm (65%), ATRI (63%), and sAPQ (57%). Hence, these data lead to disputing the current values of 12 of the 18 acoustic norms.

Acoustic Measures of Sung /u/

Fundamental Frequency/Perturbation Measures

Male F_o

The simultaneous 99% confidence interval for the mean ranged from 135.74 Hz to 214.42 Hz and did not contain the norm of 119.5 Hz. Not only did the males in this sample exhibit a substantially *higher* mean, the relative power of this decision was 71%.

Female F_o

The simultaneous 99% confidence interval for the mean ranged from 291.48 Hz to 507.80 Hz and did not contain the norm of 224.3 Hz. Again the females in this sample displayed substantially *higher* means. The relative power of this decision was 81%.

Combined Jita

The simultaneous 99% confidence interval for the mean ranged from 24.32 us to 56.88 us and did not contain the norm of 83.2 us. This sample exhibited a substantially *lower* mean; in fact, the upper limit of the confidence interval for the mean was more than 20 points lower than the norm. This translates into maximum available power (99%) despite the sample size n = 28.

Combined PPQ

The simultaneous 99% confidence interval for the mean ranged from 0.42% to 0.72% and did not contain the norm of 0.84%. This sample exhibited a

substantially *lower* mean; in fact, the upper limit of the confidence interval for the mean was more than 10 points lower than the norm. The relative power of this decision was 89%.

Combined vFo

The simultaneous 99% confidence interval for the mean ranged from 1.41% to 2.47% and did not contain the norm of 1.1%. This sample exhibited a substantially *higher* mean than the norm. The relative power of this decision was 78%.

Combined Jitt

The simultaneous 99% confidence interval for the mean ranged from 0.74% to 1.22%. The interval contained the norm of 1.04%; thus, this sample corroborated the currently employed norm.

Combined RAP

The simultaneous 99% confidence interval for the mean ranged from 0.41% to 0.71%. The interval contained the norm of 0.68; hence, this sample corroborated the currently employed norm.

Combined sPPQ

The simultaneous 99% confidence interval for the mean ranged from .84% to 2.08%. The interval contained the norm of 1.02%; hence ,this sample corroborated the currently employed norm.

In summary, the norms for 5 out of 8 Fundamental Frequency Perturbation Measures can be disputed. The strengths of the decisions can be ranked in terms

of relative power associated with each: Jita (99%), PPQ (89%), and vFo (78%). Finally, the female F_O was stronger than the male F_O(81% - 71% respectively).

Amplitude Perturbation Measures

Combined ShdB

The simultaneous 99% confidence interval for the mean ranged from 0.133 dB to 0.247 dB and did not contain the norm of 0.35. This sample exhibited a *lower* mean than the reported norm. The relative power of the decision was at maximum strength: 99%.

Combined Shim

The simultaneous 99% confidence interval for the mean ranged from 1.42% to 2.70% and did not contain the norm of 3.81. This sample exhibited a *lower* mean than the reported norm. The relative power of the decision was at maximum strength; 99%.

Combined sAPQ

The simultaneous 99% confidence interval for the mean ranged from 5.14% to 9.34% and did not contain the norm of 4.23%. This sample displayed a *higher* mean than the reported norm, and the relative power of the decision was only 72%.

Combined vAm

The simultaneous 99% confidence interval for the mean ranged from 9.47% to 14.39% and did not contain the norm of 8.2%. This sample displayed a *higher* mean than the reported norm, and the relative power of the decision was 76%.

Combined APQ

The simultaneous 99% confidence interval for the mean ranged from 1.36 dB to 3.30 dB and trapped the norm of 3.07 dB. This sample corroborated the established norm.

In summary, norms for 4 out of 5 combined Amplitude Perturbation Measures can be disputed. The strength of the decision associated with each measure can be ranked in terms of the relative power as follows: ShdB (99%), Shim (99%), vAm (76%), and sAPQ (72%).

Noise Related Measures

Combined NHR

The simultaneous 99% confidence interval for the mean ranged from 0.072 to 0.128 and did not contain the norm of 0.19. This sample exhibited a substantially *lower* mean and the relative power of the decision was at maximum power (99%).

Combined VTI

The simultaneous 99% confidence interval for the mean ranged from 0.018 to 0.042 and did not contain the norm of 0.061. This sample exhibited a substantially lower mean, and the relative power of the decision was at maximum power (99%).

Combined SPI

The simultaneous 99% confidence interval for the mean ranged from 22.28 to 66.18 and did not contain the norm of 14.12. This sample exhibited a substantially *higher* mean; however, the relative power of the decision was only 69%.

In summary, norms for 3 out of 3 Noise Related Measures can be disputed. The strength of the decision associated with each measure can be ranked in terms of the relative power as follows: NHR (99%), VTI (99%), SPI (69%).

Tremor Related Measures

Combined ATRI

The simultaneous 99% confidence interval for the mean ranged from 5.14% to 9.10% and did not contain the norm of 4.37%. This sample exhibited a *higher* mean than the norm; however, the relative power of this decision was 69%.

Combined FTRI

The simultaneous 99% confidence interval of the mean ranged from 0.78% to 1.90% and trapped the norm of 0.95%. This sample thus corroborated the norm.

In summary the norms for one out of two tremor-related measures can be disputed.

Fftr & Fatr

Norms do not exist for either Fftr or Fatr measures since each is indexed relative to the individual subject's actual pitch or fundamental frequency. The means and standard deviations are displayed separately in table 17 below for males and females since the measures are directly related to the relative fundamental frequency. The data are as follows:

TABLE 17

Fftr and Fatr Measures Sung /u/

	Males (n = 13)	Females (n = 15)
Fftr	$\bar{X}$ = 4.72 (SD = .449)	$\bar{X}$ = 4.86 (SD = .536)
Fatr	$\bar{X}$ = 4.76 (SD = .475)	$\bar{X}$ = 4.93 (SD = .568)

When simultaneous 99% confidence intervals are constructed about the mean for each of these measures, the following results, found in Table 18 below, are obtained.

Table 18

Fftr and Fatr Simultaneous 99% Confidence Interval Sung /u/

	Males (n = 13)	Females (n = 15)
Fftr	4.23 < u < 5.23	4.30 < u < 5.42
Fatr	4.23< u < 5.29	4.34 < u < 5.52

The set of 18 Acoustic Measures for sung /u/

The strength of the decisions regarding the overall set of 18 acoustic measures for sung /u/ can be ranked by relative power associated with each: NHR (99%), ShdB (99%), Shim (99%), Jita (99%), VTI (99%), PPQ (89%), female F_0 (81%), vFo (78%), vAm (76%), sAPQ (72%), male F_0 (71%), SPI (69%), and ATRI

(69%). Hence, these data lead to disputing the current values of 13 of the 18 acoustic norms.

Phonatory Measures

Male Ranges

Physiological Frequency Range of Phonation - Low

The simultaneous 99% confidence interval for the mean ranged from 78.16 Hz to 113.30 Hz and contained the norm of 80.1 Hz. The sample corroborated the established norm.

Physiological Frequency Range of Phonation - High

The simultaneous 99% confidence interval for the mean ranged from 550.91 Hz to 832.95 Hz and trapped the norm of 674.6 Hz. This sample corroborated the established norm.

Physiological Frequency Range of Phonation - Semitones

The Simultaneous 99% confidence interval for the mean ranged from 30.35 semitones to 36.89 semitones and contained the norm of 35 semitones. Hence, the sample corroborated the established norm.

Musical Frequency Range of Phonation - Low

The simultaneous 99% confidence interval for the mean ranged from 82.79 Hz to 110.45 Hz and contained the norm of 84.5 Hz. The sample corroborated the established norm.

Musical Frequency Range of Phonation - High

The simultaneous 99% confidence interval for the mean ranged from 546.94 Hz to 822.46 Hz and trapped the norm of 682.9 Hz. The sample corroborated the established norm.

Musical Semitones

The simultaneous 99% confidence interval for the mean ranged from 30.43 semitones to 35.99 semitones and contained the norm of 35 semitones. The sample corroborated the established norm.

Average Conversational Fo - Marvin Williams Passage

The simultaneous 99% confidence interval for the mean ranged from 103.04 Hz to 150.42 Hz and contained the norm of 119.5 Hz. The sample corroborated the established norm.

Male Maximum Phonation Times

MPT /ɑ /

The simultaneous 99% confidence interval for the mean ranged from 20.15 s to 35.77 s and contained the norm of 34.6 s. The sample corroborated the established norm.

MPT /i/

The simultaneous 99% confidence interval for the mean ranged from 23.01 s to 40.35 s and trapped the norm of 29.89 s. This sample corroborated the established norm.

MPT /u/

The simultaneous 99% confidence interval for the mean ranged from 20.39 s to 40.87 and contained the norm of 29.96 s. Hence, this sample corroborated the established norm.

MPT sung /ɑ/

The simultaneous 99% confidence interval for the mean ranged from 17.48 s to 33.14 s and contained the norm of 25.31 s. The sample corroborated the established norm.

MPT sung /i/

The simultaneous 99% confidence interval for the mean ranged from 17.54 s to 39.80 s and trapped the norm of 26.95 s. This sample corroborated the established norm.

MPT sung /u/

The simultaneous 99% confidence interval for the mean ranged from 19.27 s to 37.41 and contained the norm of 25.53 s. Hence, this sample corroborated the established norm.

S/Z Ratio

The simultaneous 99% confidence interval for the mean ranged from 0.881 s to 1.519 s and contained the norm of 1. Hence, this sample corroborated the established norm.

Female Ranges

Physiological Frequency Range of Phonation - Low

The simultaneous 99% confidence interval for the mean ranged from 148.44 Hz to 191.02 Hz and did not contain the norm of 140.02 Hz. This sample exhibited a *higher* mean, and the relative power of the decision was 69%.

Physiological Frequency Range of Phonation - High

The simultaneous 99% confidence interval for the mean ranged from 968.25 Hz to 1103.99 Hz and did not contain the norm of 1121.5 Hz. This sample exhibited a *lower* mean than the norm. However, the relative power of the decision was only 63%.

Physiological Frequency Range of Phonation - Semitones

The Simultaneous 99% confidence interval for the mean ranged from 28.66 semitones to 33.26 semitones and did not contain the norm of 35 semitones. This sample exhibited a *lower* mean than the established norm. The relative power of the decision was 88%.

Musical Frequency Range of Phonation - Low

The simultaneous 99% confidence interval for the mean ranged from 154.59 Hz to 194.59 Hz and did not contain the norm of 139.2 Hz. This sample exhibited a substantially *higher* mean than the established norm. The relative power of the decision was 75%.

Musical Frequency Range of Phonation - High

The simultaneous 99% confidence interval for the mean ranged from 1049 Hz to 1294.98 Hz and contained the norm of 1109.2 Hz. This sample corroborated the established norm.

Musical Semitones

The simultaneous 99% confidence interval for the mean ranged from 30.78 semitones to 34.16 semitones and did not contain the norm of 35 semitones. The sample exhibited a *lower* mean, and the relative power of the decision was 75%. Although the norm was corroborated for the upper limit of the MFRP range, the lower limit for the MFRP was at least 30 Hz higher than the norm; thus, the total Musical Semitone range was narrower.

Average Conversational Fo - Marvin Williams Passage

The simultaneous 99% confidence interval for the mean ranged from 190.62 Hz to 230.98 Hz and contained the norm of 224.3 Hz. The sample corroborated the established norm.

Female Maximum Phonation Times

MPT /ɑ/

The simultaneous 99% confidence interval for the mean ranged from 15.82 s to 27.94 s and contained the norm of 25.7 s. The sample corroborated the established norm.

MPT /i/

The simultaneous 99% confidence interval for the mean ranged from 18.15 s to 32.89 s and trapped the norm of 24.5 s. This sample corroborated the established norm.

MPT /u/

The simultaneous 99% confidence interval for the mean ranged from 17.84 s to 33.18 and contained the norm of 22.69 s. Hence, this sample corroborated the established norm.

MPT sung /ɑ/

The simultaneous 99% confidence interval for the mean ranged from 13.53 s to 31.35 s and contained the norm of 17.46 s. The sample corroborated the established norm.

MPT sung /i/

The simultaneous 99% confidence interval for the mean ranged from 16.83 s to 39.09 s and trapped the norm of 20.59 s. This sample corroborated the established norm.

MPT sung /u/

The simultaneous 99% confidence interval for the mean ranged from 16.66 s to 40.64 and contained the norm of 20.73 s. Hence, this sample corroborated the established norm.

S/Z Ratio

The simultaneous 99% confidence interval for the mean ranged from 1.05 s to 1.51 s and did not contain the established norm of 1. This sample exhibited a higher mean than the norm; however, the relative power of this decision was only 61%.

Respiratory and Glottal Efficiency Measures

Male Subjects

FVC

The simultaneous 99% confidence interval for the mean ranged from 89.18% to 117.58% and contained the norm of 100%. This sample corroborated the established norm.

FEV 1.0

The simultaneous 99% confidence interval for the mean ranged from 79.14% to 119.84% and contained the norm of 100%. This sample corroborated the established norm.

FEF 25% - 75%

The simultaneous 99% confidence interval for the mean ranged from 39.58% to 160.16% and contained the norm of 100%. There was one outlier (creating an SD of 53.81); however, even without the outlier, the confidence interval trapped the norm. Hence, this sample corroborated the established norm.

MFR

The simultaneous 99% confidence interval for the mean ranged from 136.87 ml/s to 299.01 ml/s and did not contain the norm of 101 ml/s. Moreover, the simultaneous 99% confidence interval constructed in this sample does not even overlap the confidence interval for the mean MFR reported with the norms (Hirano, 1981, p. 28, reported a confidence interval ranging from 86 ml/s to 117 ml/s). This sample of males exhibited a substantially *higher* mean; in fact, the lower limit of the confidence interval constructed for the mean MFR is approximately 20 ml/s higher than the upper limit of the corresponding confidence interval reported in the literature. Hirano himself indicates that a value as extreme as 200 ml/s arises from a sample exhibiting abnormal phonation.

Female Subjects

FVC

The simultaneous 99% confidence interval for the mean ranged from 93.01% to 120.37% and contained the norm of 100%. This sample corroborated the established norm.

FEV 1.0

The simultaneous 99% confidence interval for the mean ranged from 90.55% to 116.87% and contained the norm of 100%. This sample corroborated the established norm.

FEF 25% - 75%

The simultaneous 99% confidence interval for the mean ranged from 71.56% to 114.08% and contained the norm of 100%. Hence, this sample corroborated the established norm.

MFR

The simultaneous 99% confidence interval for the mean ranged from 156.13 ml/s to 244.71 ml/s and did not contain the norm of 92 ml/s. Again, the simultaneous 99% confidence interval constructed in this sample does not even overlap the confidence interval for the mean MFR reported with the norms (Hirano, 1981, p. 28, reported a confidence interval ranging from 79 ml/s to 107 ml/s). This sample of females exhibited a substantially *higher* mean; in fact, the lower limit of the confidence interval constructed for the mean MFR is approximately 50 ml/s higher than the upper limit of the corresponding confidence interval reported in the literature. Moreover, the mean MFR of this sample is so extreme that the sample would be considered as exhibiting abnormal phonation.

CHAPTER V

CONCLUSION AND DISCUSSION

After all is said and done, and the singers have sung; the data have been collected, analyzed by the MDVP, and subjected to statistical analysis; and the results examined, the question initially posed is still appropriate: "Why is it necessary to collect quantifiable data of sung production when many singers have had wonderful careers without the aid of a lot of numbers and machinery?" The application of technology to the singing voice yields significant pedagogical advantages. It provides a wonderful device to help the teacher reach the wide range of cognitive processes in the vocal studio and allows the singer to have immediate objective feedback. The student is able to see and recognize (as well as hear) what the teacher also hears and sees.

Clinically, quantifiable measures are also critical. Therefore, the implications of having a baseline of singer norms to evaluate discrepancies from that norm is strikingly obvious. It is absolutely necessary to compare singers to singers. The old saying of comparing apples to apples and not apples to oranges is appropriate here.

The conventional norms furnished by Kay Elemetrics and norms adjusted by the American Institute for Voice and Ear Research served as the basis for comparison. In particular, the acoustic norms (excluding the Fo) were from the Kay Elemetrics MDVP, and the Fo, phonatory, and respiratory measures were from the norms used by Sataloff at the American Institute for Voice and Ear Research. These were used as the framework against which to compare the various measures produced by singers.

The decision to compare the acoustic results of this study with the normative threshold values as used by the MDVP of the CSL (Deliyski, 1993) was

made for several reasons. First, it grew out of a desire to evolve an accurate comparison of data by using the same program for contrasting the results of this study with published norms. Second, this system is becoming the most widely used in clinics and voice laboratories for analysis of both spoken and sung phonation (it is now frequently being used in lieu of the Sona-Graph, which is no longer being manufactured by Kay Elemetrics). Finally, it is understood that currently accepted normative threshold values should not be treated as "set in stone" (Kay Elemetrics, 1993, p. 182).

The Kay Elemetrics norms were derived from a total sample of only 68 persons. This sample was comprised of 15 persons (7 male, 8 female) with normal voice production and 53 patients (25 male, 28 female) with laryngeal diseases. Also the threshold values refer exclusively to the /ɑ/ vowel and, moreover, were collected on only a single occasion with one trial per subject, i.e., no warm-up or apparatus familiarization preparatory trials.

The research described in this dissertation is an expansion of the idea and use of the MDVP. The population comprised of nonpathological singers with normal voice function and each of the 28 subjects repeated 5 trials over 3 occasions using both spoken and sung phonation to examine the vowels /ɑ/, /i/, and /u/. Potentially important variables reported by the subjects may well include the following: vocal development, physical well-being, and the time of data collection. In regard to vocal development, 2 subjects reported that they have had only 1 voice teacher, whereas 9 subjects reported having 2 teachers, 12 subjects reported having 3 teachers, 4 reported having 4 teachers, and 1 reported having 6 teachers. The majority of subjects also reported having only limited speaking voice use. However, 5 subjects reported heavier speaking voice use ranging from a receptionist/secretary, to restaurant hostess, lifeguard and swimming instructor, to a baby-sitter. All of the subjects were actively involved in

ensemble singing and taking voice lessons, and the majority of subjects were involved in opera workshop. Additionally, 5 subjects had singing jobs as well. In regard to physical well-being, the majority of subjects (19) reported that they eat late at night near bedtime sometimes, while only 2 reported never eating late and 7 reported that they eat late at night often. Also, less than half of the subjects (12) reported being involved in some type of exercise which ranged from aerobics to swimming and intramural sports. In regard to the time of data collection, 26 out of the 28 subjects had data collection times that fell within 1 to 1 1/2 hours of each other for at least two out of the three occasions [1].

Because only the /ɑ/ vowel was used by Deliyski (1993), one would suspect that there would be differences between the collected data of this study when comparing the /i/ and /u/ vowels of both spoken and sung phonation with the currently accepted norms of the MDVP. Variations were detected not only between the currently published normative data and the current study in the acoustic domain of the /i/ and /u/ vowels, but also of the /ɑ/ vowel in both spoken and sung phonation.

ACOUSTIC DOMAIN

The following is a brief summary of the variation between the published acoustic norms and the results of this study of the vowels /ɑ/, /i/, and /u/ in spoken and sung phonation.

In regard to spoken phonation, data led to disputing 8 out of the 18 published acoustic norms for the /ɑ/ vowel (NHR, sPPQ, FTRI, PPQ, vAm, Jita, RAP, and VTI); 8 out of the 18 norms differed for the /i/ vowel (FTRI, NHR, ShdB, APQ, Shim, SPI, sPPQ, and PPQ); and 10 out of the 18 acoustic norms differed for the /u/ vowel (FTRI, NHR, VTI, ShdB, Shim, APQ, sPPQ, Jita, PPQ, and SPI).

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[1] The above information has been included for the benefit of future research.

In regard to sung phonation, data for 12 out of the 18 published acoustic norms for the /ɑ/ vowel deviated from the threshold values (Jita, PPQ, sAPQ, vAm, ATRI, female Fo, vFo, male Fo, RAP, and NHR); 12 out of 18 norms differed for the /i/ vowel (Jita, SPI, PPQ, vFo, ShdB, Shim, sPPQ, female Fo, male Fo, vAm, ATRI, and sAPQ); and 13 out of 18 norms differed for the /u/ vowel (NHR, ShdB, Shim, Jita, VTI, PPQ, female Fo, male Fo, SPI, and ATRI).

TREMOR RELATED MEASURES

Of the four tremor related measures--FTRI, ATRI, Fftr, and Fatr--two of the measures (Fftr and Fatr) were not included in the comparison of norms and the results of this current study since there are no published norms. It is important to remember that there can be both frequency tremor (a regular or periodic long term pitch modulation of the voice) and amplitude tremor (a regular or periodic long term amplitude modulation of the voice). These tremor measures correspond with vibrato in singers. Titze (1995) stated that, although vibrato can be described as a fluctuation of fundamental frequency (pitch) and amplitude (intensity), it is actually a pattern itself rather than a deviation. There is still much that is not understood about the production of vibrato. Therefore, application of the measures FTRI, ATRI, Fftr, and Fatr in examining vibrato is extremely important in facilitating a deeper understanding of the origin, properties, and production of vibrato.

This knowledge will be invaluable for both clinical and pedagogical application. Although the original intent of the tremor related indices of MDVP was for use in evaluating disorders such as spasmodic dysphonia (Deliyski, Orlikoff, & Kahane, 1991), these tremor indices are directly related to the singer's use of vibrato. However, if the measures of FTRI, ATRI, Fftr and Fatr are employed, it is now possible to gain new insight into understanding and

measuring vibrato rate, as well as intensity, and the separation of fundamental frequency and amplitude properties in vibrato production.

An important aspect of the graphic representation of the acoustic parameters in MDVP involves the smoothing factor in measuring perturbation. As one starts at the 12:00 point of the MDVP diagram (Appendix KK) where Jita is and moves clockwise around the circle to vFo, the smoothing factor increases. Therefore the effect of vibrato will be evidenced primarily in vFo and sometimes in sPPQ. With the amplitude indices starting with ShdB and moving clockwise toward vAm, the vibrato will be evident in sAPQ and vAm. The measure of VTI may also be elevated (particularly found in Baritones in this study). In summary, the measures that will describe characteristics of vibrato include primarily vFo, vAm, FTRI, ATRI, Fftr and Fatr. Additional effects of vibrato may be detected in the measures sPPQ, sAPQ, and VTI.

PHONATORY AND RESPIRATORY DOMAINS

The following is a brief summary of the variation between the published and practiced phonatory and respiratory norms and the results of this study.

The data of this sample for males corroborated the norms for all of the phonatory measures examined (PFRP, MFRP, Ave Fo, MPT's, and s/z ratio). However, the data of this sample for females had some variations with the norm. The MFRP, Average Fo using Marvin Williams, and all of the MPT's Corroborated the norms. The sample exhibited a higher mean than the norm of the PFRP measures (low, high, and semitones), thus suggesting that new norms are appropriate for singers. This sample also exhibited a higher mean in regard to the s/z ratio, indicating the necessity of establishing new norms (although the relative power of the decision was only 61%).

In regard to PFT's, the data of this sample for both males and females agreed with the established norms, thereby not corroborating the hypothesis. However, both males and females in this sample exhibited a substantially *higher* mean than the established norm for MFR, thus indicating that new norms are appropriate.

NEED FOR SIMULTANEOUS INTERVAL STATISTICS

This current study (and the nature of the MDVP diagram itself) simultaneously investigated a large array of indicators in each of three domains. It was, therefore, necessary to take precautions in order to protect against committing Type I errors. A strategy of investing 99% confidence, simultaneously spread over the set of 18 acoustic measures, was used. Subsequently, a system of simultaneous 99% confidence was established for testing the individual measures of the 20 interrelated phonatory and respiratory measures (16 phonatory and 4 respiratory). By using a set of simultaneous confidence intervals, the following decisions about each measure were made: (1) the value of a norm was corroborated if it fell within the respective confidence interval; (2) a directional departure from the value of the norm was established when it fell outside the respective confidence interval; (3) the overall width of a confidence interval was inversely related to the power of the decision regarding the displacement of the obtained result from the value of the norm cited in the literature and conventionally employed in laboratories. Data were combined over three occasions and used to execute this procedure.

The conventional itemization strategies (i.e., successive consideration) tend to compound the risk of the Type I error. The risk increases exponentially, not linearly, as the number of indicators increases and becomes a more acute problem as the number of indices increases. In order to accommodate simultaneous

investigation of an array of indicators, a set of simultaneous confidence intervals must be constructed (this can be done by using an expansion of the Dunn-Bonferroni procedure). The use of simultaneous confidence intervals was demonstrated to be far superior to traditional strategies which successively establish confidence intervals, thereby compounding Type I errors when examining the entire array of indices.

This strategy additionally contributed to the power of the diagnostic phase by using contemporary statistical strategies. It permits one to prioritize the nature of differences requiring attention, thereby allowing for prescriptive therapy. As such, it opens the door for a symptomology of disorders.

RELIABILITY OF INSTRUMENTATION

In previous studies most researchers have used five to six (or more) trials to gauge each measure or indicator precisely. This research indicates that no more than three trials are required to produce the same level of precision when examining normal voice function. This finding is consistent with the recommendations of Guilford (1956) in which three was the optimal number of raters for measuring psychological phenomena. However, a study by Scherer, Vail, and Guo (1995) suggests that ten tokens are required to achieve reliability of voice perturbation values. It would be of great benefit clinically to examine a three -trial procedure for analysis of pathological voices with the MDVP. Although preliminary findings support this procedure, further study is warranted before this application should ensue.

In the current study, digitized responses produced median reliability in the upper nineties, nearly perfect, when employed over each of the five trials over 3 occasions (within 17 of 19 measures) nearly unanimous.

FUTURE

The research contained in this dissertation goes beyond the various papers and conference presentations which discuss the need for standardization of objective measures. It suggests that excellent reliability of instrumentation, incisive methodology, and a move toward standardization can only be as good as the strategy employed for controlling the high risk of committing Type I errors, which abound in presenting research results for each of several indicators successively.

The outstanding clinical implication of this study is the need for recalibration of norms that provide representative spoken and sung norms for an accurate baseline for comparison with pathological voices. In applying this knowledge and technology to the clinical voice laboratory, one has to consider practical aspects as well as what clinical insight can be gleaned from examining the acoustic parameters of the voice. If a voice patient presents with a main complaint of hoarseness, a voicing sample should be collected using the MDVP. Practically, 10 tokens or trials would be out of the question, five would still be too time consuming, three would be reasonable, and one would be optimal. It would not be time-effective to print out all three samples. Many labs are collecting and digitally saving only one sample. However, if the patient is a singer, samples of both spoken and sung phonation need to be collected. Clinicians will most likely use the /ɑ/ vowel, because it is reported on in the literature most widely and is therefore more easily compared. If a patient is hyperfunctional, either with or without resulting pathology, he/she should have voicing samples collected at the first visit and periodically during subsequent prescriptive therapy to assess and document improvement. If the patient is a candidate for surgery, data needs to be collected both pre- and post-surgery. A possible time-line for data collection

following surgery could include objective measures analysis at two weeks post, six weeks post, and three months post-surgery.

There are many pedagogical implications for the application of the new technology and knowledge available today. There is now the ability to create biofeedback to enhance instructional performance. An item of particular benefit includes the ability to separate the components of vibrato. It is now possible for students to be able to see the pitch and intensity variations while they also hear their own recorded sample. The teaching of vibrato does not have to stay a mystery. The teacher no longer has to use only imagery such as "keep a shimmer in the tone" or tell the student "you need a faster vibrato" when in fact the rate may be fine but the intensity parameter warrants examination. Another issue key to any singer's maturity, most often referred to as placement, is the ability to see and understand the singer's formant and the resonance phenomenon of the voice. Other issues that may be examined include the onset of a tone and the harmonic spectrum series of different vowels. Along with improving instructional strategies, students can load source signals from CD's and Tapes into a Sona-Graph or CSL and examine the acoustic characteristics of world-class singers in any genre. Previously, the only way students learned from the masters was by perceptually emulating what they heard on a recording or in a studio. However, perception does not necessarily include good use of technique. Often as singers concentrate on the end product or sound, they forget about the process of creating sound (technique) and begin to manipulate their system without even realizing it.

The door is wide open for future research possibilities, such as the effect of the laryngeal position in relationship to a full harmonic spectrum. Pedagogically, the studio voice teacher could apply this by tracking the difference between a shallow and a full sound by examining the harmonic spectrum on a spectrograph. The student could be instructed to do a series of repeated bio-feedback practice

tasks during the week. The instructor could monitor or track for progress at the next lesson by capturing and analyzing another spectrogram.

Another future research project might be the study of occurrences (frequency) of Harsh Glottal Attacks (HGA's) in the beginning voice student. This could be addressed by looking both at the initial onset of a vowel or the incidence within a phrase. The studio voice teacher could also apply this by using the Visi-pitch. The same procedure of using bio-feed back practice tasks during the week and monitoring or tracking progress, as mentioned above could be used for tracking the reducing HGA's at vocal onsets. The teacher could even have the student make print-outs of practice attempts, if the teacher so desired.

One might also wish to examine vibrato in more detail. Vibrato could be examined by studying the following: How does the rate of vibrato differ when one is singing (a) Wagner vs. Donizetti, (b) Wagner vs. an Italian Art Song, (c) a French Art Song vs. a German Art Song, (d) a Broadway Ballad vs. a Classical Art Song, (e) a Jazz Ballad vs. a Broadway tune, (f) a Pop tune vs. a Jazz tune? Another question might be does pitch variation vs. intensity variation differ from style to style? This could be examined by using the MDVP and also the spectrogram choice from the CSL program.

A few precautionary guidelines for future research must be given. If the research involves examining multiple indices, as is possible with MDVP, a series of simultaneous confidence intervals is essential. Contemporary statisticians have found it advantageous to examine not only intervals, but also trends and directionality rather than point estimates such as means and standard deviations. Finally, when delineating measures, it is critical to utilize the best device available to record sound so that artifacts are eliminated; thus, the current standard for noiseless sound recording is the Digital Audio Tape (DAT).

Numerous perceptible disparities in acoustic norms apparently exist for spoken and sung phonation. In order to clarify and corroborate these distinctions, it is necessary for one to collect and analyze data from numerous larger samples. Cross validation between these studies will yield stable norms for use in evaluating singers. The magnitude and patterns of the disparity in norms for measures in the acoustic domain has particular implications not only for clinical assessment and prescription but also--perhaps more importantly--for evolving pedagogical designs.

The implications of this study are far reaching for both clinical and pedagogical applications. If the role of the teacher is to instruct and guide the student toward reaching his/her potential, the teacher must use all possible resources to better serve the needs of each student. It would be remiss to ignore the pedagogical advantages that exist from the application of technology that has developed over the past five to seven years in voice science.

The job of the clinician is to accurately diagnose the functional aspects of phonation. Programs such as the MDVP allow for an expedient process of specifically pinpointing, in quantifiable terms, the problematic characteristics of phonation such as short-term cycle-to-cycle variation in frequency or amplitude. The application of this technology allows the clinician to better serve the needs of the patient in a more accurate and timely manner.

The melding together of music and medicine, along with the technology of voice science, has given birth to a new era of voice care. It is exciting to be on the ground floor and be involved in the burgeoning field of Arts Medicine.

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APPENDIX A

SUBJECT DEMOGRAPHICS

SUBJECT DEMOGRAPHICS

Subjects (n = 28)

Subject Population				
	Male		Female	
Age	$\bar{X}$ = 22	SD = 2.16	$\bar{X}$ = 22.13	SD = 2.90
Height	$\bar{X}$ = 5' 9"	SD = 2.39"	$\bar{X}$ = 5' 5"	SD = 2.38"
Weight	$\bar{X}$ = 187 lbs.	SD = 30.13 lbs.	$\bar{X}$ = 147 lbs.	SD = 35.5 lbs.

Tamarac Spirometer Ethnicity Delineation		
	Male	Female
*100%	12	12
+85%	1	3

* = Caucasion, Hispanic, European

+ = Black, East Indian, Pakistani, Asian, Arabic

SUBJECT DEMOGRAPHICS

Subjects (n = 28)

		Voice Category			
		Soprano	Mezzo	Tenor	Baritone
Academic Year	FR	1	1	1	1
	SOPH	-	-	1	1
	JR	3	-	1	1
	SR	2	1	1	2
	GR	6	1	1	3

APPENDIX B

SUBJECT INFORMATION SHEETS

SUBJECT INFORMATION SHEETS

Dear Voice Student:

The purpose of this study will be to track objective measures of vocal development during the course of singing study. There will be three data collections three months apart: The first collection will be in october of the 1993 Fall semester, the second will be in January of the 1994 Winter semester, and the third will be in April of the 1994 Winter semester. The objective measures will include acoustic and respiratory measures. Each data collection will take 30-40 minutes.

The acoustic measures will be recorded for later analysis. The subjects will be asked to produce (a) a conversational speaking sample, (b) a physiological range of phonation, (c) a musical range of phonation, (d) five trials lasting five seconds on each vowel of a spoken sound on the vowels /ɑ/, /i/, and /u/, and (e) five trials lasting five seconds on each vowel of a sung sound on the vowels /ɑ/, /i/, and /u/.

The phonatory measures will include maximum phonation times of both spoken and sung productions on the vowels /ɑ/, /i/, and /u/, and maximum phonation of /s/ and /z/.

The respiratory measures will include (a) pulmonary function testing which helps to determine the ability of the lungs and abdomen to support speech and singing and (b) measurement of laryngeal airflow during phonation on the vowel /ɑ/ which helps to examine glottal efficiency.

If you choose to participate in this study, a licensed otolaryngologist will view your vocal folds with a laryngeal mirror to determine if there is any evidence of gross vocal pathology. If a pathology is found than you will be excluded from the study.

Please sign-up if you are interested. You will be notified in advance of the day and will need to schedule a time for the laryngeal viewing. You will also be asked to sign up for a data collection time. Because of time limitations, it is imperative that you come during the time for which you signed-up. You will be notified in regard to the assigned room.

Thank you for your participation.

Sincerely,

Sharon L. Radionoff
Ph. D. Candidate
Michigan State University

Dr. Robert Erbes
Area Chairman,
Music Education

APPENDIX C

SUBJECT CONSENT FORM

SUBJECT CONSENT FORM

The purpose of this study is to track objective measures of vocal development during the course of singing study. There will be three data collections: The first collection will be October of the 1993 Fall semester, the second will be January of the 1994 Winter semester, and the third will be in April of the 1994 Winter semester. The objective measures will include acoustic and respiratory measures. Each data collection session will require 30 minutes.

The acoustic measures will be recorded for later analysis. You will be asked to produce (a) a conversational speaking sample, (b) a physiological range of phonation, (c) a musical range of phonation, (d) five trials lasting five seconds on each vowel of a spoken sound on the vowels /ɑ/, /i/, and /u/, and (e) five trials lasting five seconds on each vowel of a sung sound on the vowels /ɑ/, /i/, and /u/.

The phonatory measures will include both spoken and sung productions on the vowels /ɑ/, /i/, and /u/, and maximum phonation of /s/ and /z/.

The respiratory measures will include (a) pulmonary function testing which helps to determine the ability of the lungs and abdomen to support speech and singing, and (b) measurement of laryngeal airflow during phonation on the vowel /ɑ/ which helps to examine glottal efficiency.

If you choose to participate in this study, an ENT Physician will view your vocal folds to determine if there is any evidence of gross vocal pathology. The exam is routine using standard protocol (use of a laryngeal mirror). If a nodule, polyp, cyst or other type of pathology is found, then you will be excluded from the study. If no pathology is found then you are eligible to participate with the understanding that you may withdraw at any time if you so choose from this study with no penalty.

All results will be treated with strict confidence and you will remain anonymous in any report of research findings; upon a written request and within these restrictions results may be made available to you, the subject.

If you have any questions or concerns regarding your participation in this study, please contact: Sharon L. Radionoff at (713) 960-1648 or (713) 796-2001.

I, the undersigned, indicate my voluntary agreement to participate in this research study.

_____ _____

Subject Signature Date

APPENDIX D

QUESTIONAIRE FOR EACH SUBJECT

SUBJECT QUESTIONAIRE

NAME_____

SEX M F

AGE_____

SUBJECT #_____

DATE_____

TIME OF DATA COLLECTION_____

YEAR IN SCHOOL_____

YEARS OF VOICE STUDY_____

NUMBER OF DIFFERENT TEACHERS_____

1. Did you have private voice lessons (college, high school, or at other times) before your first year of college study? If yes, for how long?

2. Do you play a brass or woodwind instrument(s)? If yes, what do you play and for how long have you played it (them)?

FOR THE FOLLOWING ITEMS PLEASE CIRCLE THE APPROPRIATE ANSWER

3. Are you currently participating in ensemble singing? yes no

4. Are you currently directing an ensemble? yes no

5. Are you currently participating in an opera/musical theatre production? yes no

6. Do you perform with a live band? yes no

7. Are you actively involved in athletics? yes no
   Please explain if your answer was yes

8. Are you an aerobics instructor? yes no

9. Do you have a job? yes no
   If yes what type of job?

10. Do you eat late at night, near bedtime? never sometimes often

11. How much telephone talking time each day? 0-3 hrs 3-5 hrs 4+ hrs

12. Comments on physical health at the time of this data collection:

APPENDIX E

SUBJECT INSTRUCTION SHEET

SUBJECT INSTRUCTION SHEET

1. Pleas fill out the preliminary information at the top of the questionaire.

2. You will be given 2 practice items for the acoustic data collection. As the cue is given, respond by producing a spoken sound on the vowel /ɑ/ and then a sung sound on the vowel /ɑ/.

3. The acoustic data collection will begin.

4. The phonatory and respiratory measures will be taken after the acoustic measures. Please listen carefully to the instructions.

5. The phonatory and respiratory data collection will begin.

6. After the data collection is complete, please fill out the rest of the questionaire.

Thank you for participating

APPENDIX F

AMERICAN INSTITUTE FOR VOICE
AND EAR RESEARCH

OBJECTIVE EVALUATION PROTOCOL

AMERICAN INSTITUTE FOR VOICE AND EAR RESEARCH

OBJECTIVE EVALUATION PROTOCOL disk #: _____ filename(s): _____ _____

JOSEPH SATALOFF, M.D., D. Sc.
ROBERT T. SATALOFF, M.D., D.M.A.
JOSEPH R. SPIEGEL, M.D.
1721 PINE STREET
PHILADELPHIA, PA 19103

(215) 545-3322
T.D.D. (215) 985-4060
FAX (215) 790-1192

OTOLOGY/NEUROTOLOGY
OCCUPATIONAL HEARING LOSS
PROFESSIONAL VOICE CARE

OTOLARYNGOLOGY/ALLERGY
HEAD AND NECK SURGERY
FACIAL PLASTIC SURGERY

TAPE # _____
MIC LEVEL _____ INPUT _____ MICROPHONE: _____
ANESTHESIA PRESENT? ☐Y ☐N EXAMINER: _____

OBJECTIVE VOICE ANALYSIS PROTOCOL ☐ PROF. VOICE USER
NAME: _____ ☐ NON-PROF. VOICE USER
DATE OF EVAL: _____ ☐ SINGER - CLASSICAL
AGE: _____ DOB: _____ ☐ SINGER - NON-CLASSICAL
SEX: ☐M ☐F HGT: _____ WGT: _____ ____ YRS. OF STUDY
PHYSICIAN: ☐RTS ☐JRS ____ # TEACHERS
MEDICAL DIAGNOSIS: _____ ☐ NON-SINGER
PROFESSIONAL SINGER? _____ VOICE TYPE: _____
SS# _____ OCCUPATION: _____

TAPE RECORD THE FOLLOWING: (• = sonograph and tape recorder)

1. STATE YOUR NAME/DATE/AGE/:

2. PHYSIOLOGICAL FREQUENCY RANGE ON /a/:
   - SLIDE MID-RANGE AND DOWN, SLIDE MIDRANGE AND UP

3. MUSICAL FREQUENCY RANGE ON /a/:
   - STEP-WISE: MIDRANGE AND DOWN, MIDRANGE AND UP

4. •SPOKEN /a/ /i/, /u/: 5x's, 5 secs. each [Program #40]
   (copy 1st /a/ onto computer)
   capture EGG waveform from last /a/ into [Program 41]

   •SUNG /a/, /i/, /u/: 5 x's, 5 secs. each [Program #40]
   (copy 1st /a/ onto computer)

   SPOKEN /a/; SUNG /a/ singer's formant [Program #36]

5. SPOKEN /a/: narrow and wide-band [Program #22, 23]

6. READING PASSAGES:
   a. MARVIN WILLIAMS

Marvin Williams is only nine. Marvin lives with his mother on Monroe Avenue in Vernon Valley. Marvin loves all movies, even eerie ones with evil villains in them. Whenever a new movie is in the area, Marvin is usually an early arrival. Nearly every evening Marvin is in row one, along the aisle.

HGA: _____/23
Time: _____

AMERICAN INSTITUTE FOR VOICE AND EAR RESEARCH

OBJECTIVE EVALUATION PROTOCOL

•b. TOWNE-HEUER READING PASSAGE [Program 37]

If I take a trip this August I will probably go to Austria. Or I could go to Italy. All of the places of Europe are easy to get to by air, rail, ship, or auto. Everybody I have talked to says he would like to go to Europe also. Every year there are varieties of festivals or fairs at a lot of places. All sorts of activities, such as food to eat, sights to see, occur. Oh, I love to eat ices seated outdoors! The people of each area are reported to like us - the people of the U.S. A. It is said that that is true, except for Paris. Aid is easy to get because the officials are helpful. Aid is always available if troubles arise. It helps to have with you a list of offices or officials to call if you do require aid. If you are lost, you will always be helped to locate your route or hotel. The local police will assist you, if they are able to speak as you do. Otherwise, a phrase book is useful. I have had to have help of this sort each trip abroad. However, it was always easy to locate. Happily, I hope, less help will be required this trip. Last trip every house or hotel was occupied. I had to ask everywhere for flats. Two earlier trips were hard because of heat or lack of heat at hotels.

HGA: _____/100 TOTAL READING TIME: _____(443)

MAXIMUM PHONATION:

spoken /a/_____ sung /a/ _____

spoken /i/_____ sung /i/ _____

spoken /u/_____ sung /u/ _____

/s/ _____ /z/ _____ s/z ratio _____

MAXIMUM PHONATION TIME FOR ADULTS (HIRANO, 1968):

MALE: 34.6 secs.(30.2-39.4);FEMALE: 25.7 secs.(22.9-28.7)

MEAN FLOW RATE:

/a/	/a/	/a/	
			FV
			T
			MFR=FV/T

NORMATIVE DATA: (Hirano, 1968)

Males: 101 ml/sec (86-117) Females: 92 ml/sec (79-107)

PULMONARY FUNCTION TESTING: (Knudson)

	FEV 1.0	FVC	FEF 25-75
Observed			
Predicted			
% Predicted			

Notes:

APPENDIX G

MICHIGAN STATE UNIVERSITY

UCRIHS APPROVAL

MICHIGAN STATE UNIVERSITY

UCRIHS APPROVAL

MICHIGAN STATE
UNIVERSITY

September 18, 1993

TO: Ms. Sharon L. Radionoff
Apt. #342
2412 Yorktown
Houston, TX 77056

RE:		
	IRB #:	93-405
	TITLE:	OBJECTIVE MEASURES OF VOCAL DEVELOPMENT DURING THE COURSE OF SINGING STUDY
	REVISION REQUESTED:	09/07/1993
	CATEGORY:	2-C,F
	APPROVAL DATE:	08/27/1993

The University Committee on Research Involving Human Subjects' (UCRIHS) review of this project is complete. I am pleased to advise that the rights and welfare of the human subjects appear to be adequately protected and methods to obtain informed consent are appropriate. Therefore, the UCRIHS approved this project including any revision listed above.

Renewal: **UCRIHS approval is valid for one calendar year, beginning with the approval date shown above.** Investigators planning to continue a project beyond one year must use the enclosed form to seek updated certification. There is a maximum of four such expedited renewals possible. Investigators wishing to continue a project beyond that time need to submit it again for complete review.

Revisions: UCRIHS must review any changes in procedures involving human subjects, prior to initiation of the change. If this is done at the time of renewal, please use the enclosed form. To revise an approved protocol at any other time during the year, send your written request to the UCRIHS Chair, requesting revised approval and referencing the project's IRB # and title. Include in your request a description of the change and any revised instruments, consent forms or advertisements that are applicable. the year, please outline the proposed revisions in a letter to the Committee.

Problems/ Changes: Should either of the following arise during the course of the work, investigators must notify UCRIHS promptly: (1) problems (unexpected side effects, complaints, etc) involving human subjects or (2) changes in the research environment or new information indicating greater risk to the human subjects than existed when the protocol was previously reviewed and approved.

If we can be of any future help, please do not hesitate to contact us at (517) 355-2180 or FAX (517) 336-1171.

Sincerely,

David E. Wright, Ph.D.
UCRIHS Chair

DEW:pjm

cc: Dr. Robert L. Erbes

OFFICE OF
RESEARCH AND GRADUATE STUDIES
University Committee on Research Involving Human Subjects (UCRIHS)
Michigan State University
225 Administration Building
East Lansing, Michigan
48824-1046
517/355-2180
FAX: 517/336-1171

MSU is an affirmative-action equal-opportunity institution

APPENDIX H.1

Fo SPOKEN /ɑ/

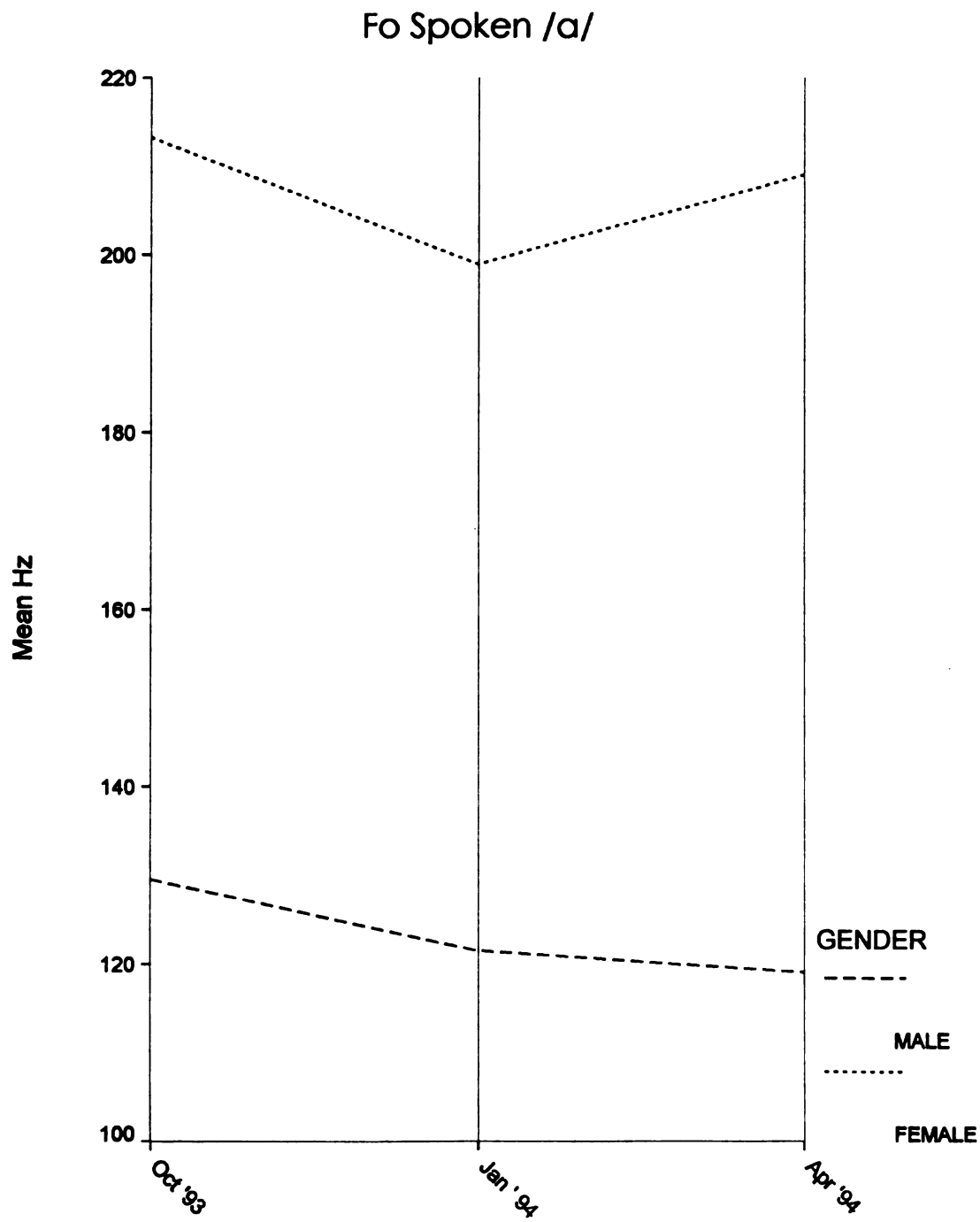

Fo Spoken /a/
220
200
180
160
140
120
100
Mean Hz
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 1

APPENDIX H.2

Jita SPOKEN /a/

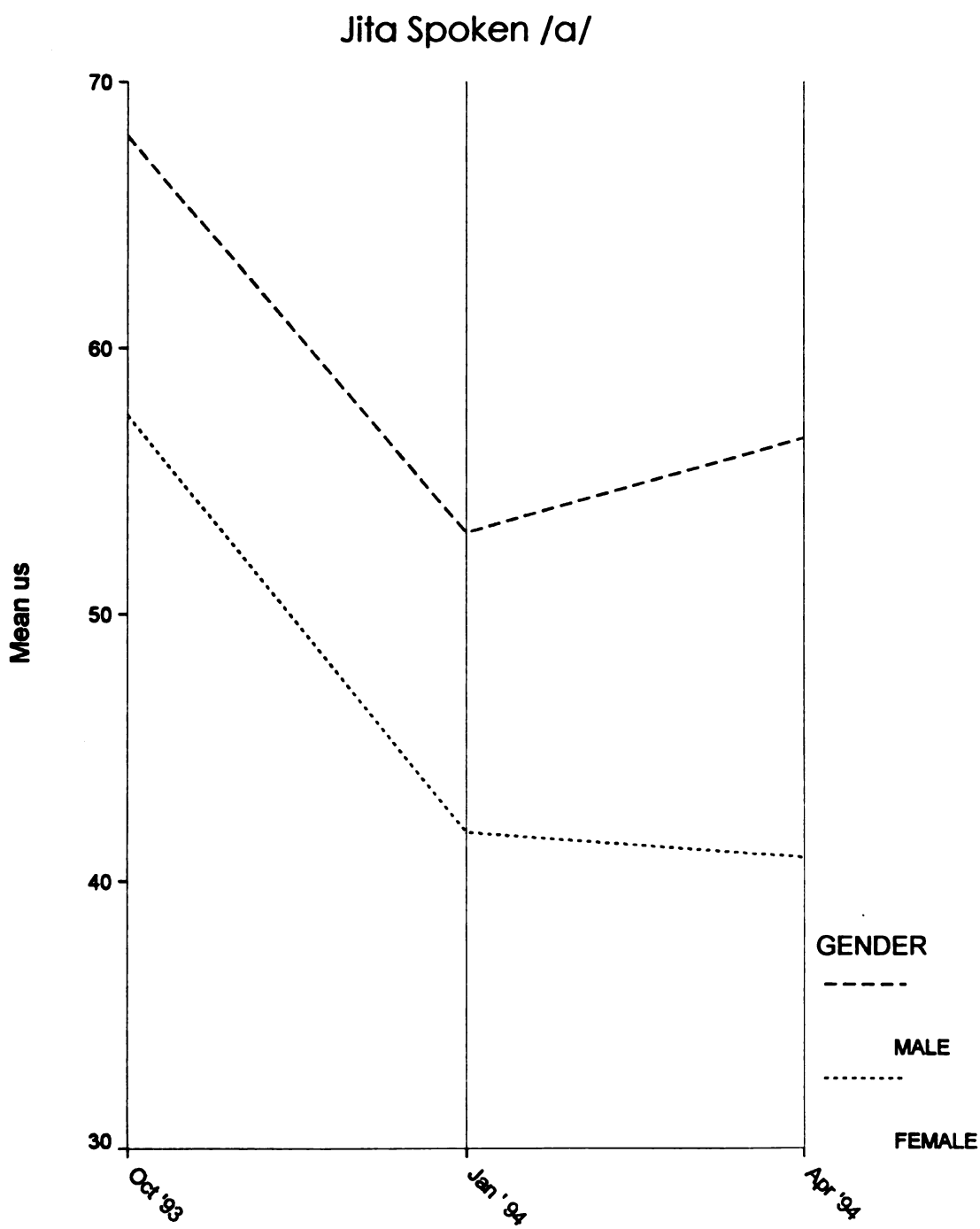

Jita Spoken /a/
70
60
50
40
30
Mean us
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 2

APPENDIX H.3

Jitt SPOKEN /a/

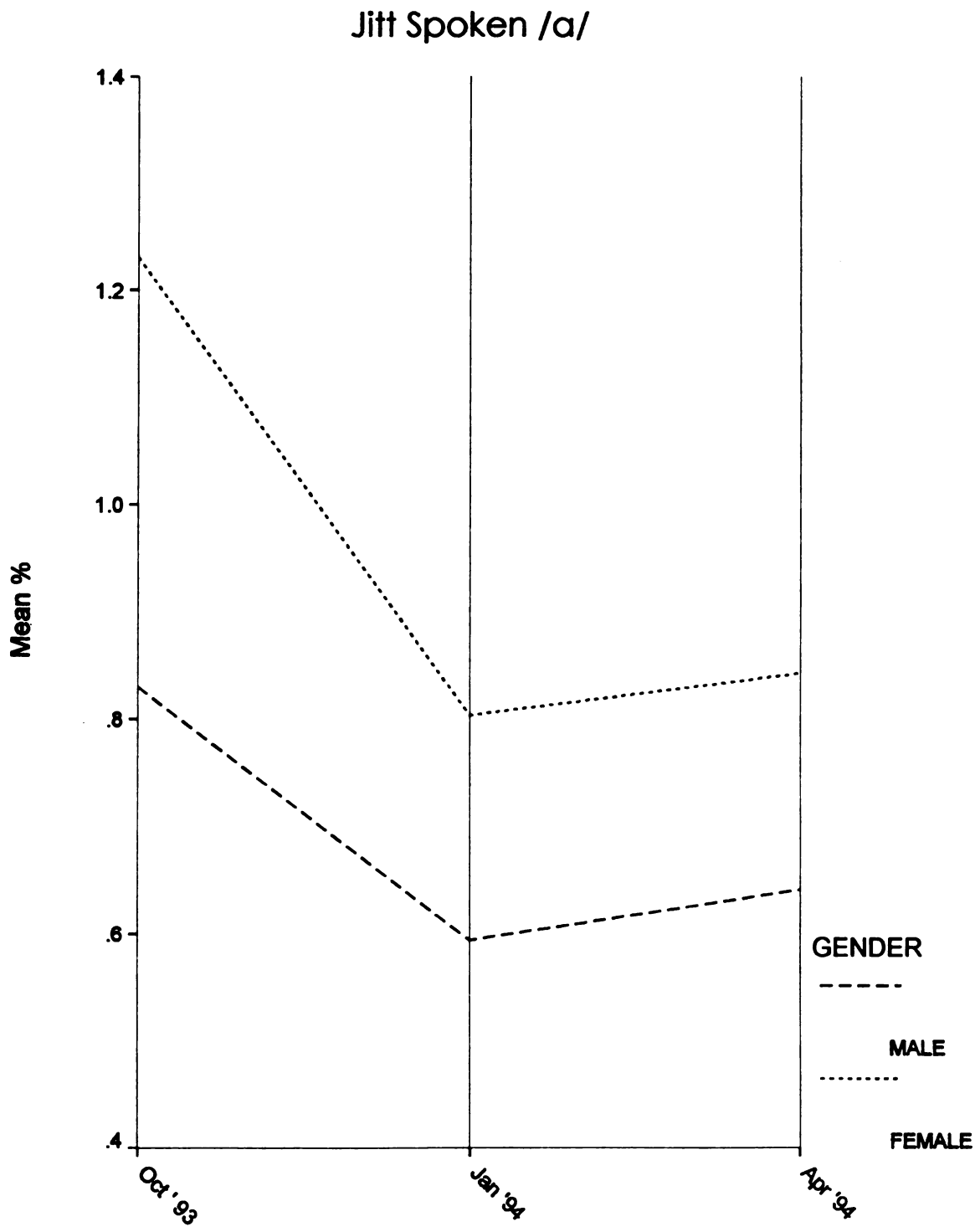

Jitt Spoken /a/
1.4
1.2
1.0
.8
.6
.4
Mean %
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 3

APPENDIX H.4

RAP SPOKEN /a/

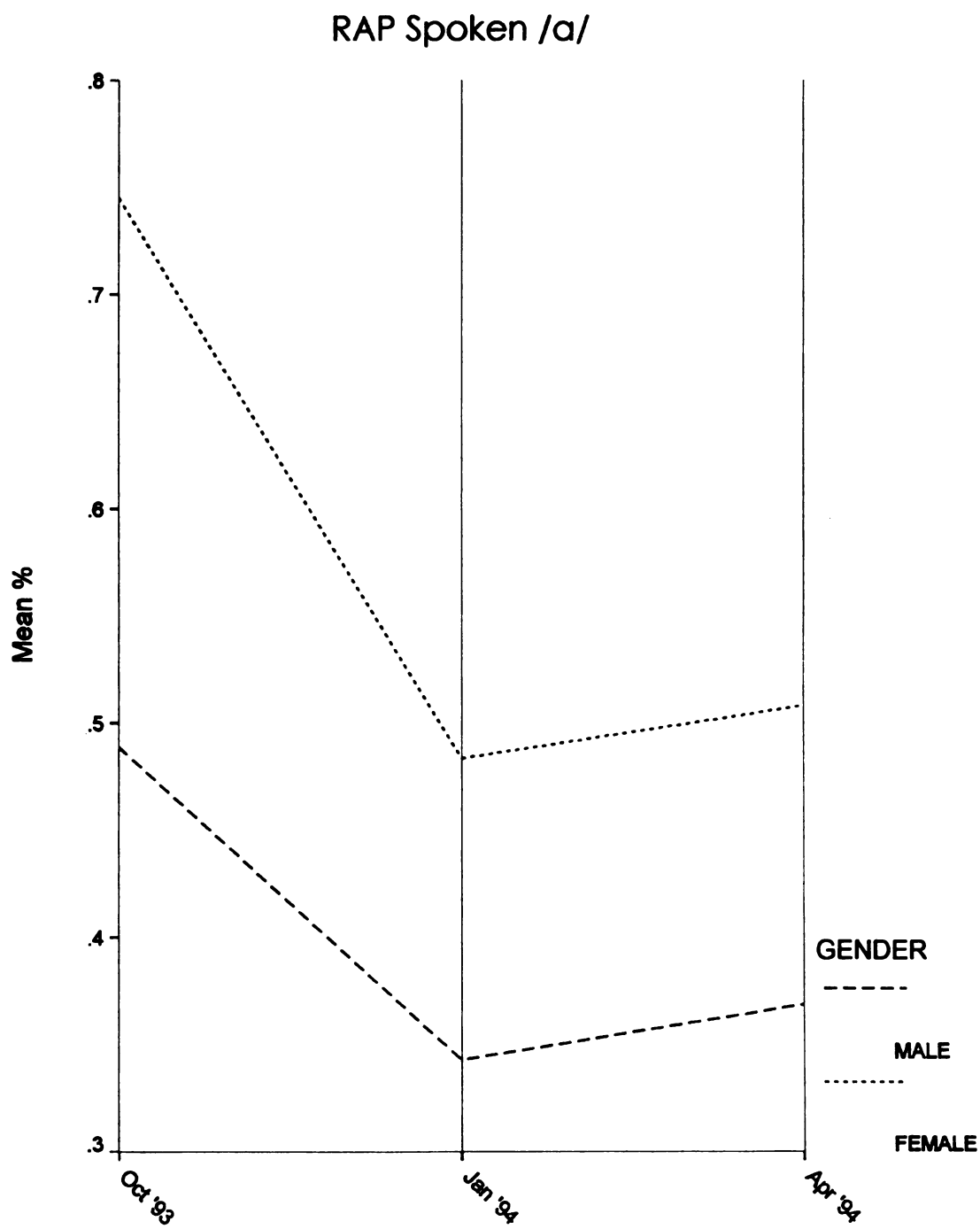

RAP Spoken /a/
.8
.7
.6
.5
.4
.3
Mean %
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 4

APPENDIX H.5

PPQ SPOKEN /a/

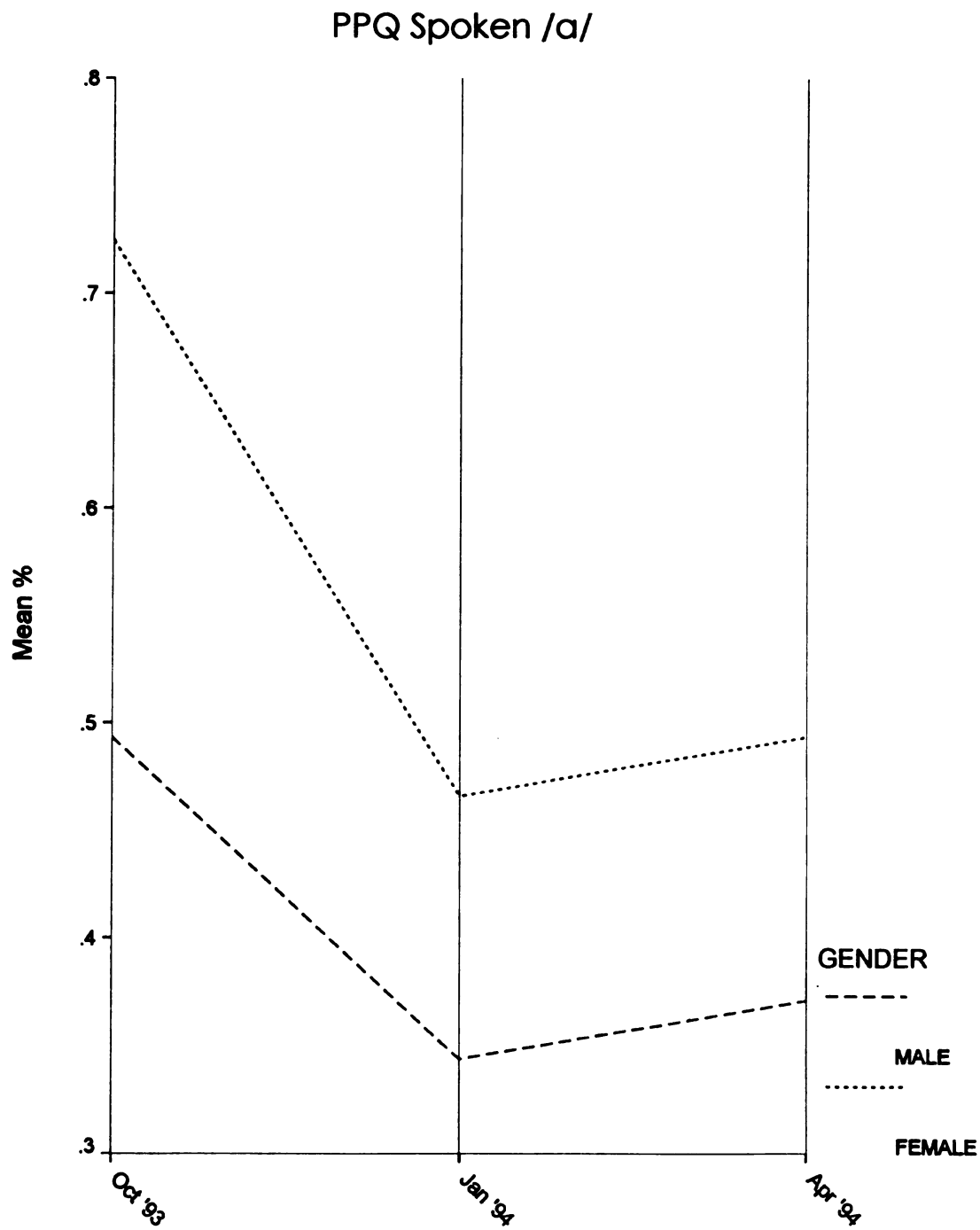

PPQ Spoken /a/
Mean %
.8
.7
.6
.5
.4
.3
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 5

APPENDIX H.6

sPPQ SPOKEN /ɑ/

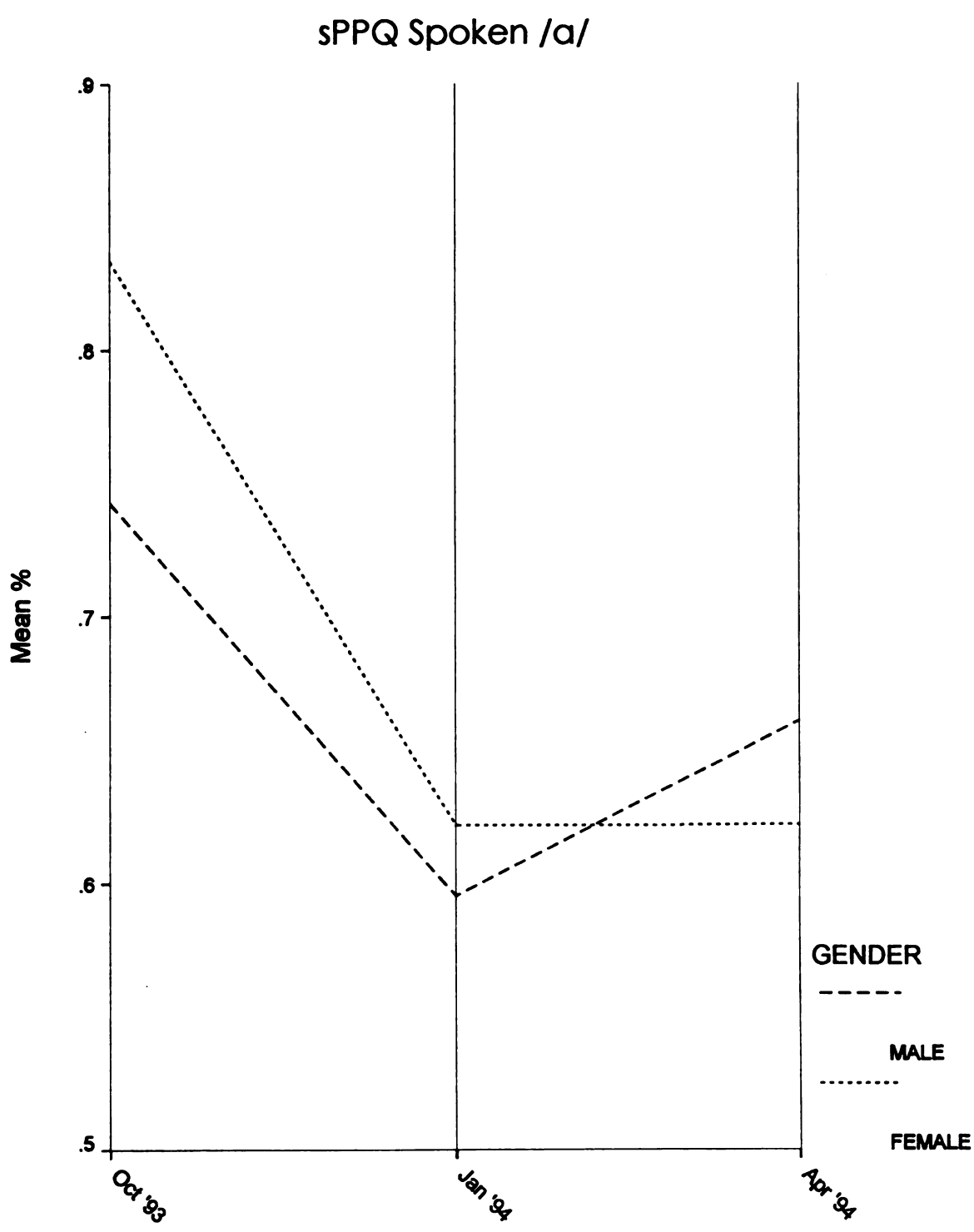

sPPQ Spoken /a/
Mean %
.9
.8
.7
.6
.5
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 6

APPENDIX H.7

vFo SPOKEN /ɑ/

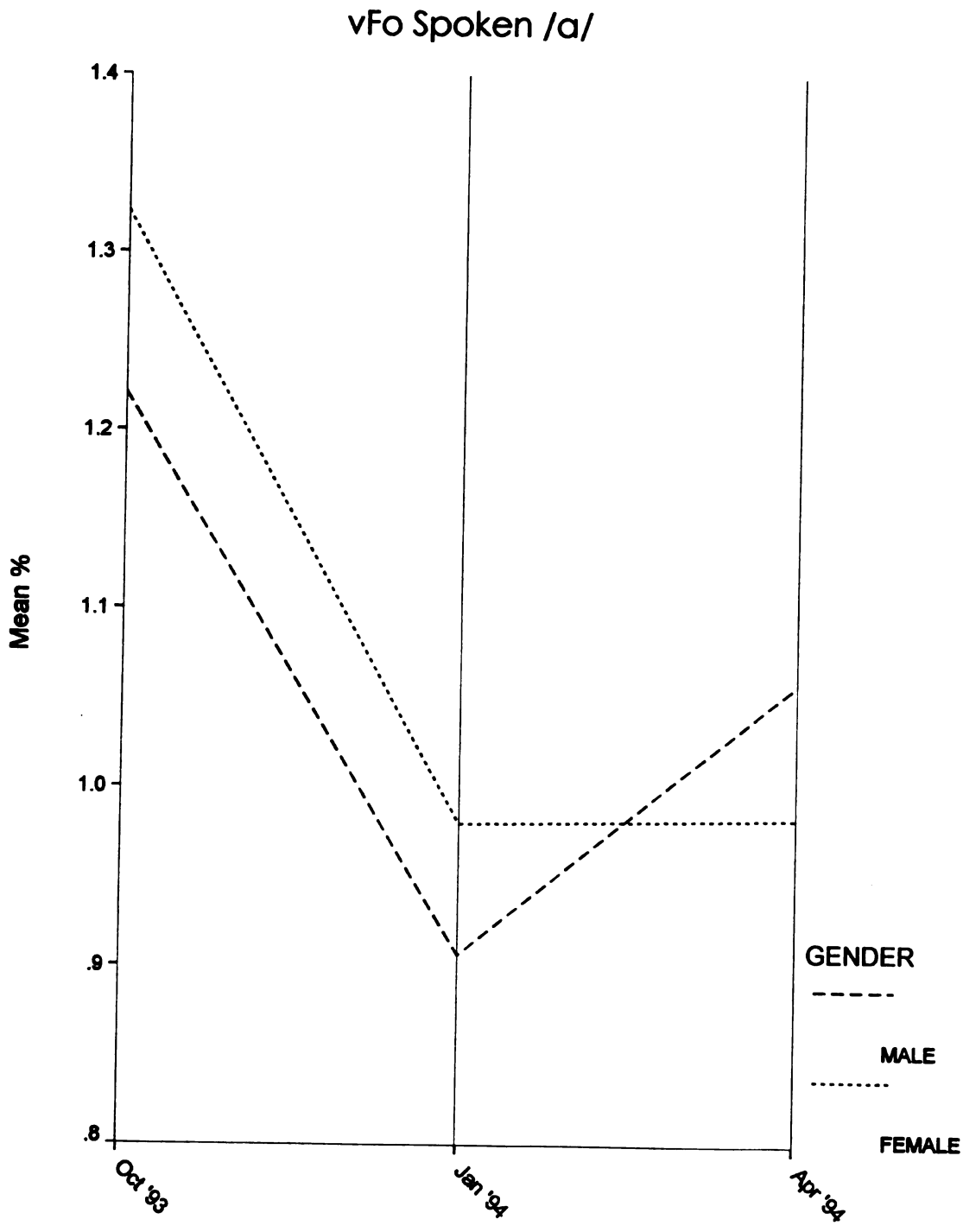

vFo Spoken /a/
Mean %
1.4
1.3
1.2
1.1
1.0
.9
.8
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 7

APPENDIX I.1

ShdB SPOKEN /ɑ/

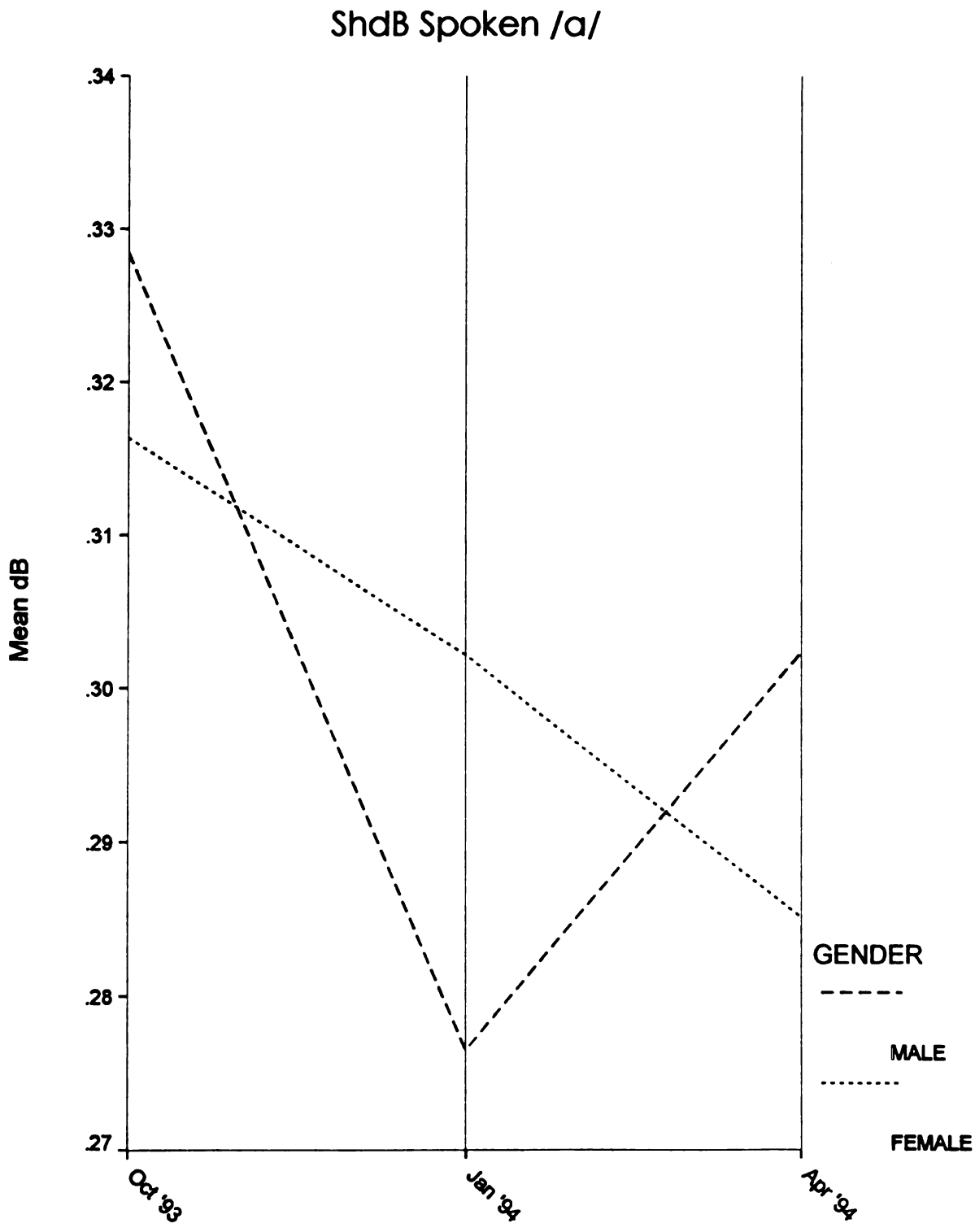

ShdB Spoken /a/
.34
.33
.32
.31
.30
.29
.28
.27
Mean dB
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 8

APPENDIX I.2

Shim SPOKEN /ɑ/

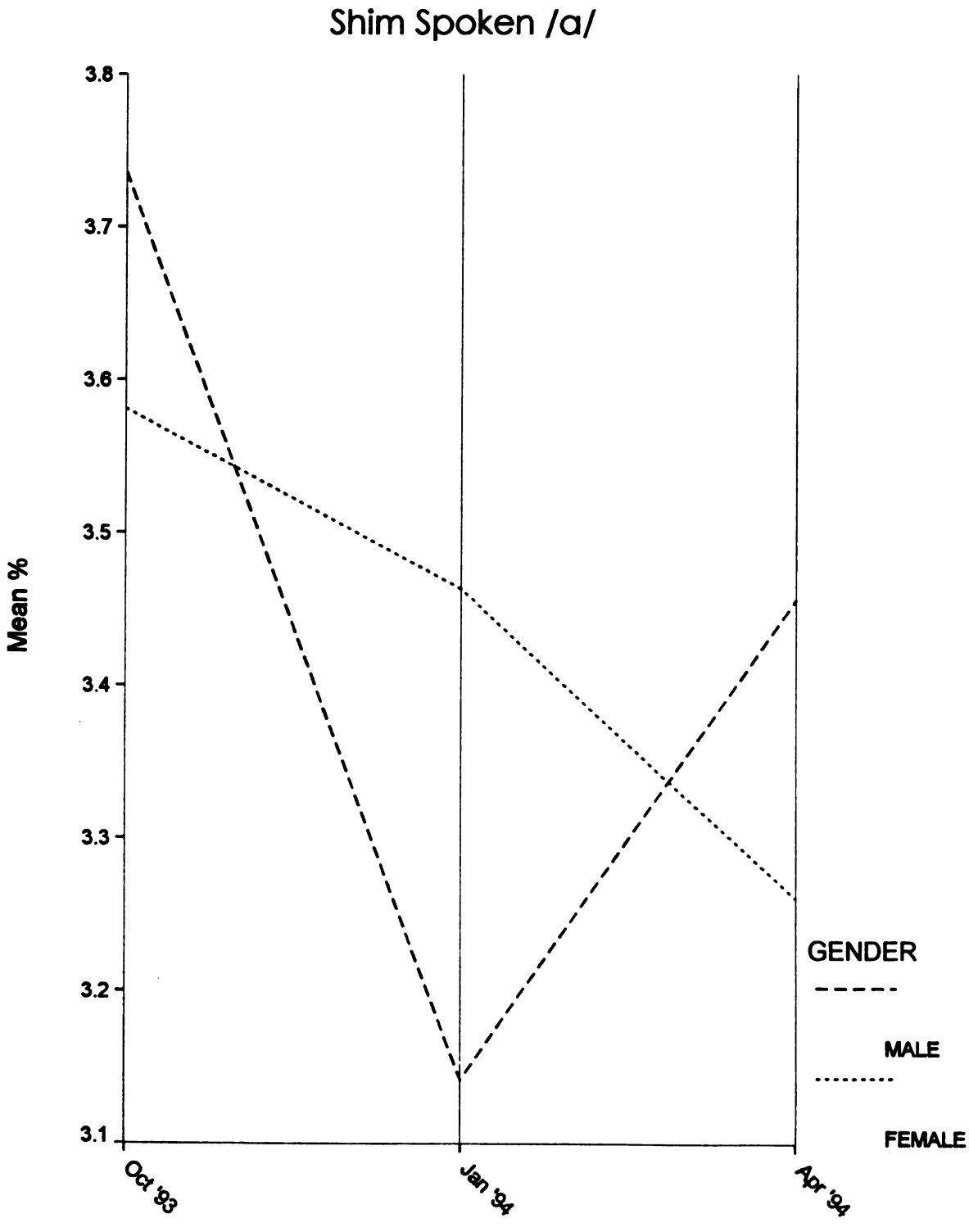

Shim Spoken /a/
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
Mean %
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 9

APPENDIX I.3

APQ SPOKEN /ɑ/

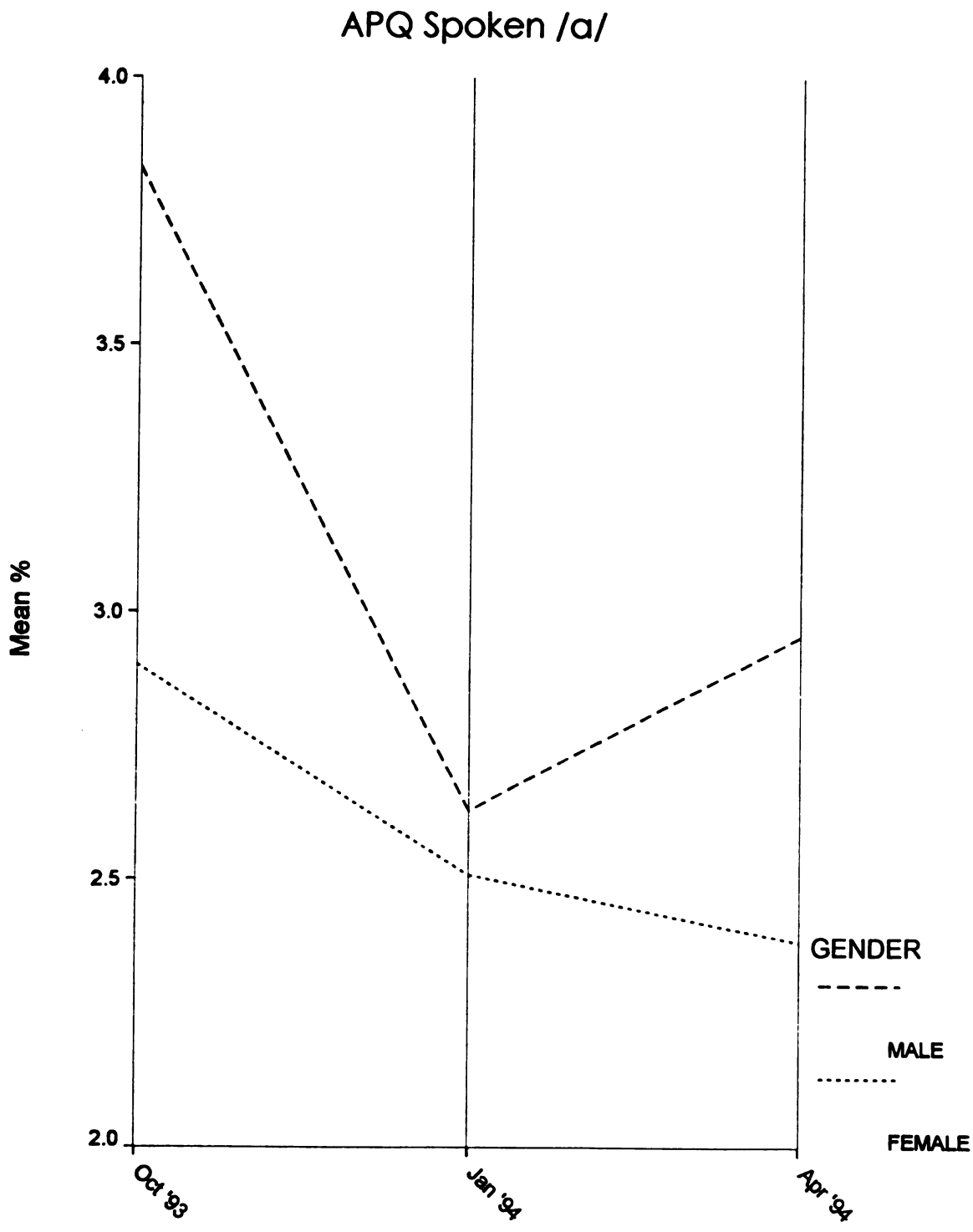

APQ Spoken /a/
4.0
3.5
3.0
2.5
2.0
Mean %
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 10

APPENDIX I.4

sAPQ SPOKEN /a/

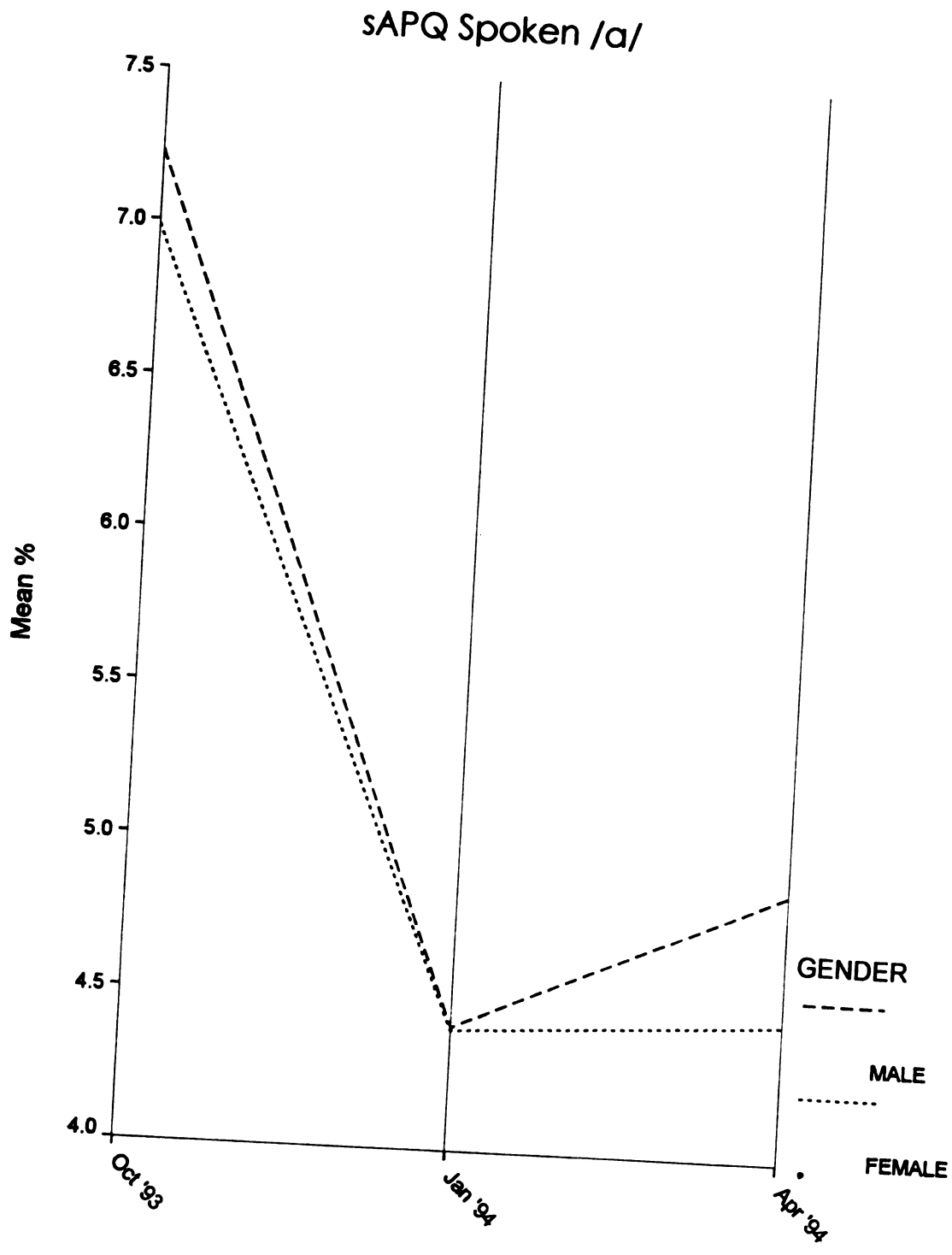

sAPQ Spoken /a/
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
Mean %
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 11

APPENDIX I.5

vAm SPOKEN /ɑ/

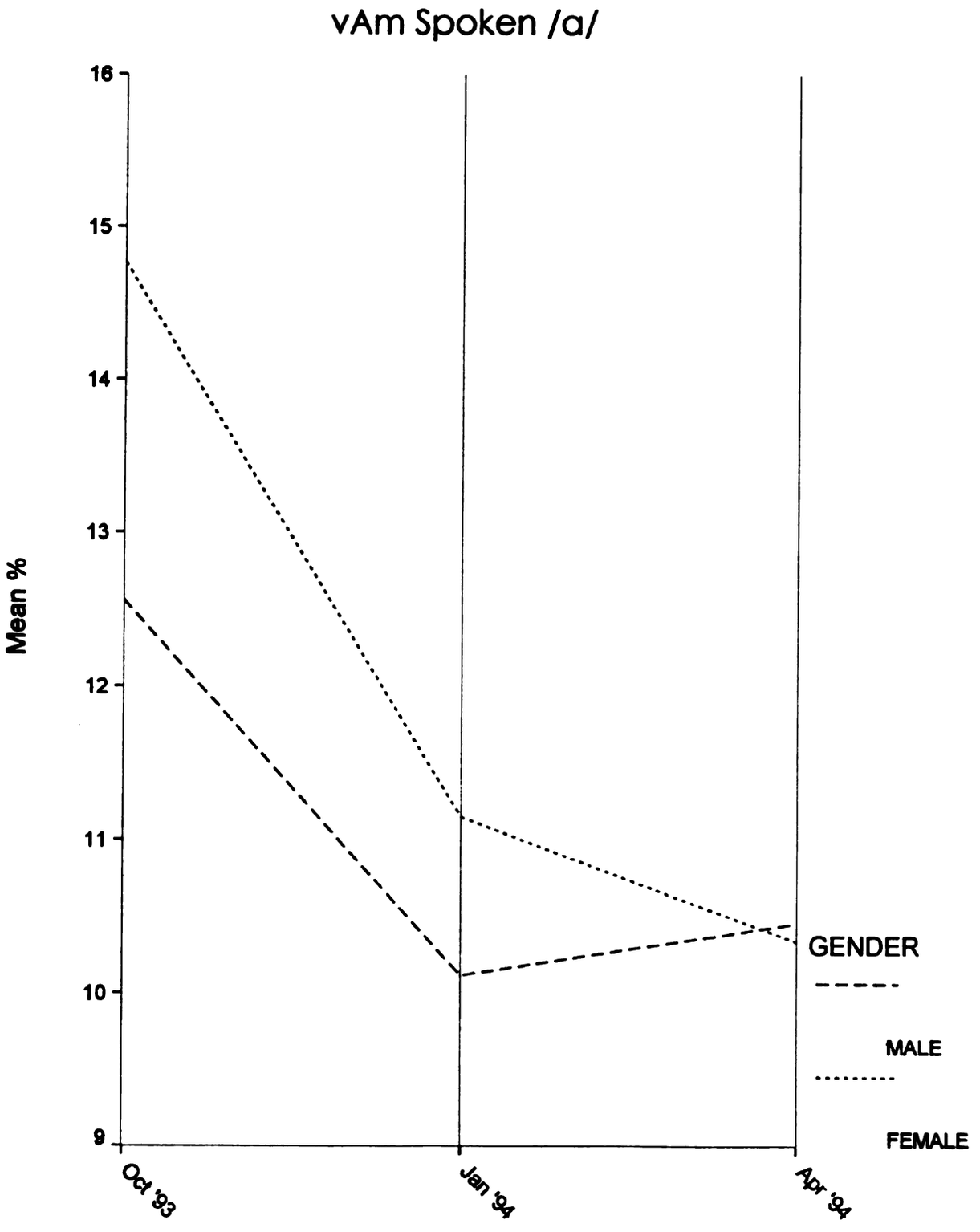

vAm Spoken /a/
16
15
14
13
12
11
10
9
Mean %
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 12

APPENDIX J.1

NHR SPOKEN /a/

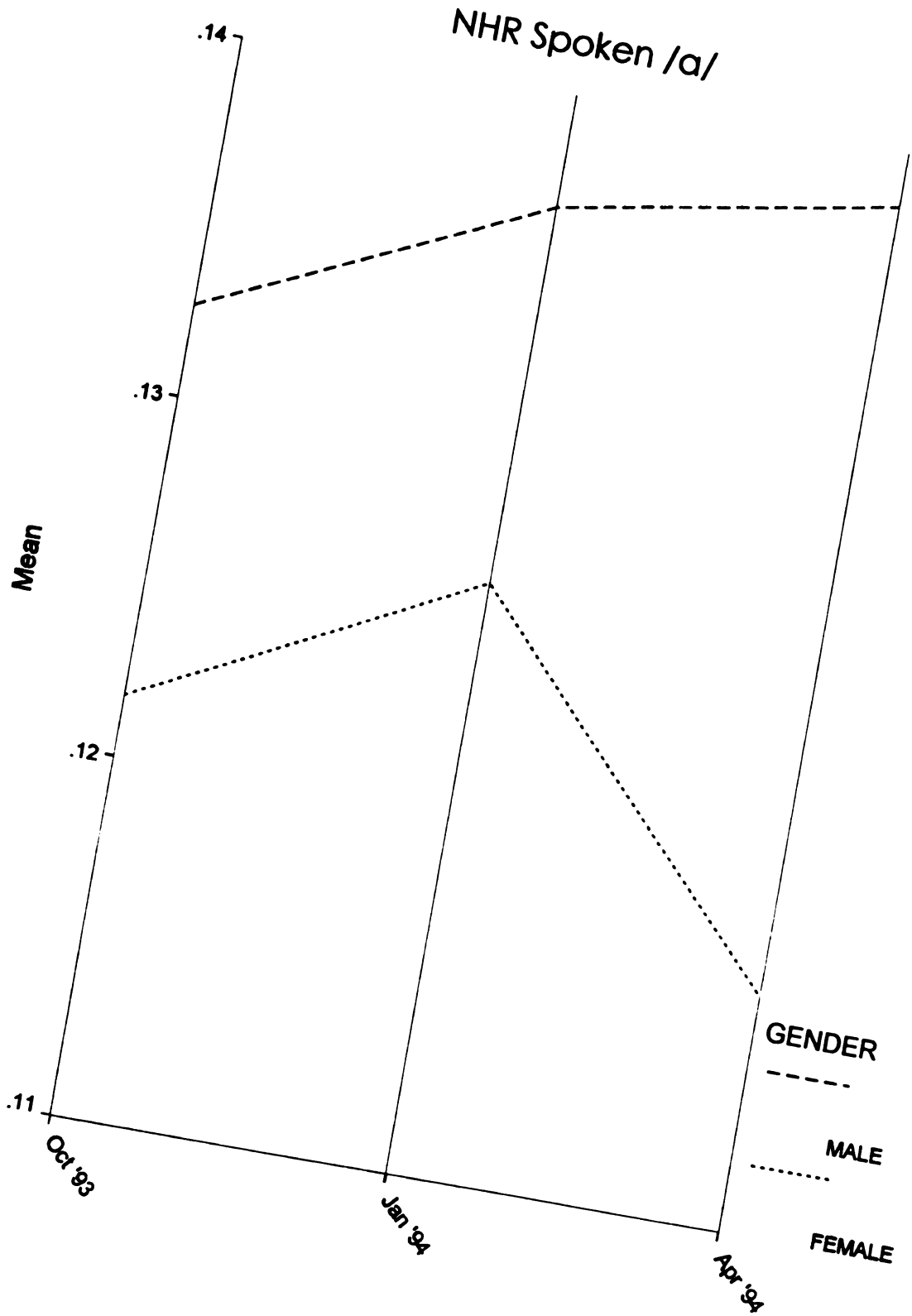

NHR Spoken /a/
.14
.13
.12
.11
Mean
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 13

APPENDIX J.2

VTI SPOKEN /a/

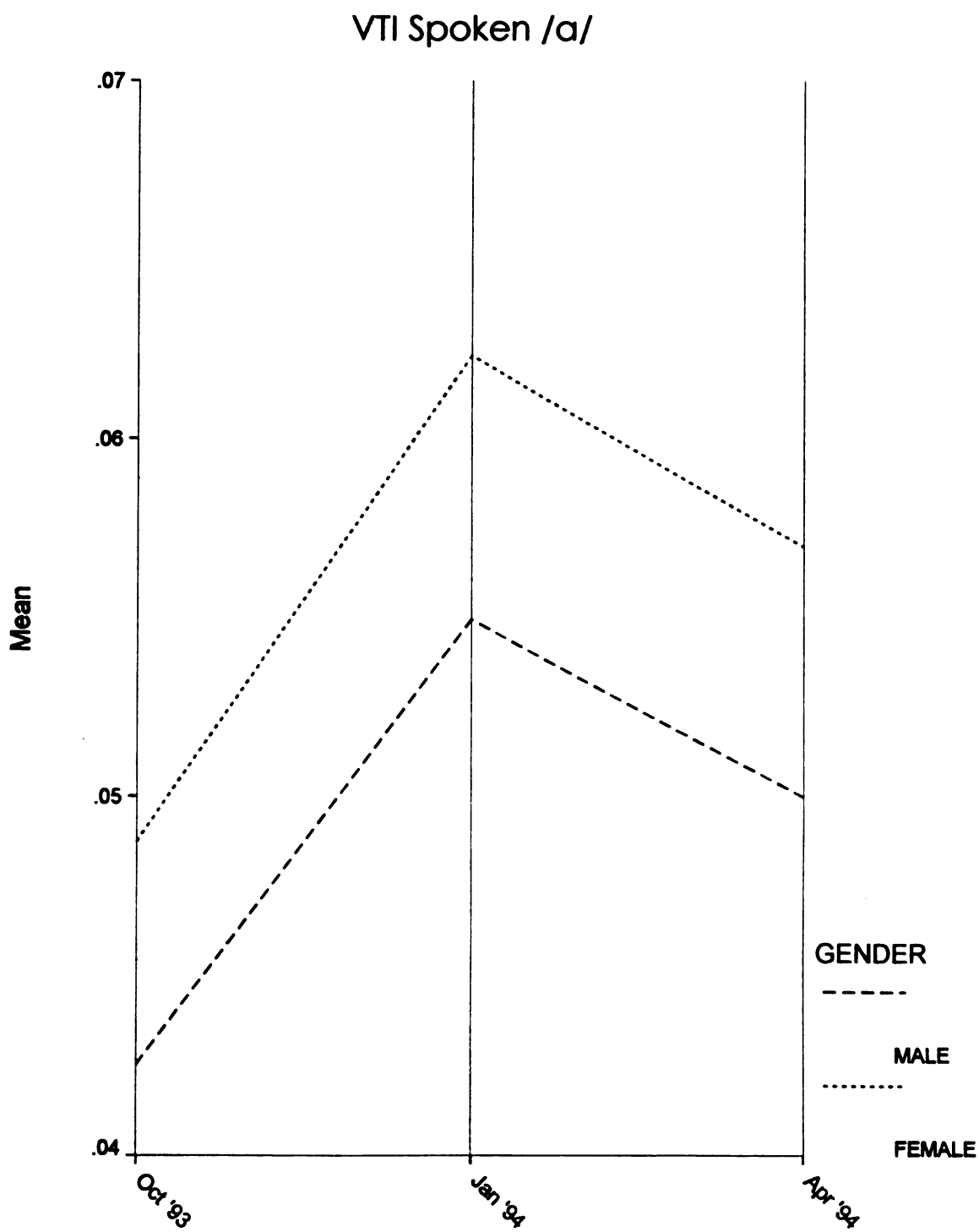

VTI Spoken /a/
.07
.06
.05
.04
Mean
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 14

APPENDIX J.3

SPI SPOKEN /a/

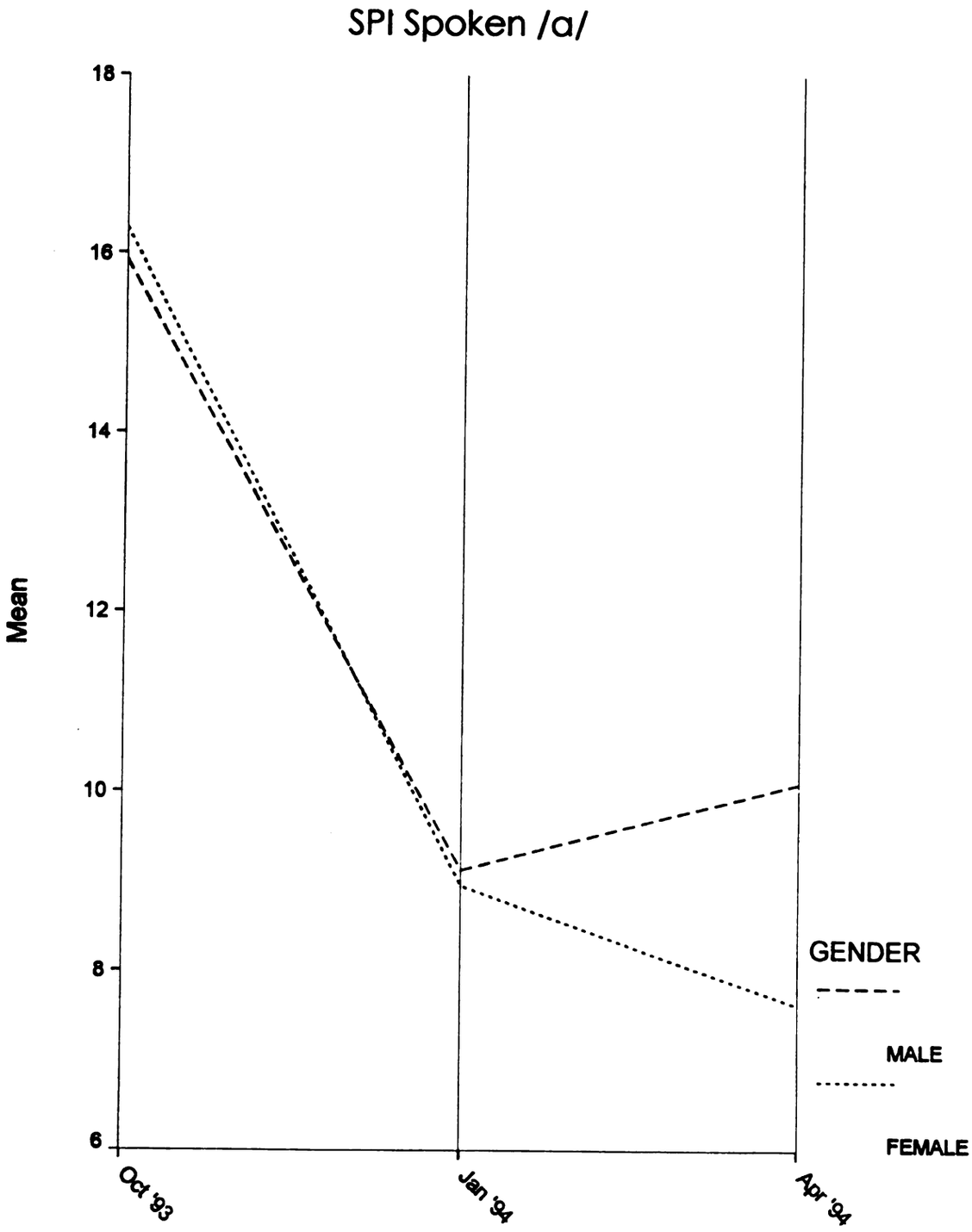

SPI Spoken /a/
18
16
14
12
10
8
6
Mean
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 15

APPENDIX K.1

FTRI SPOKEN /a/

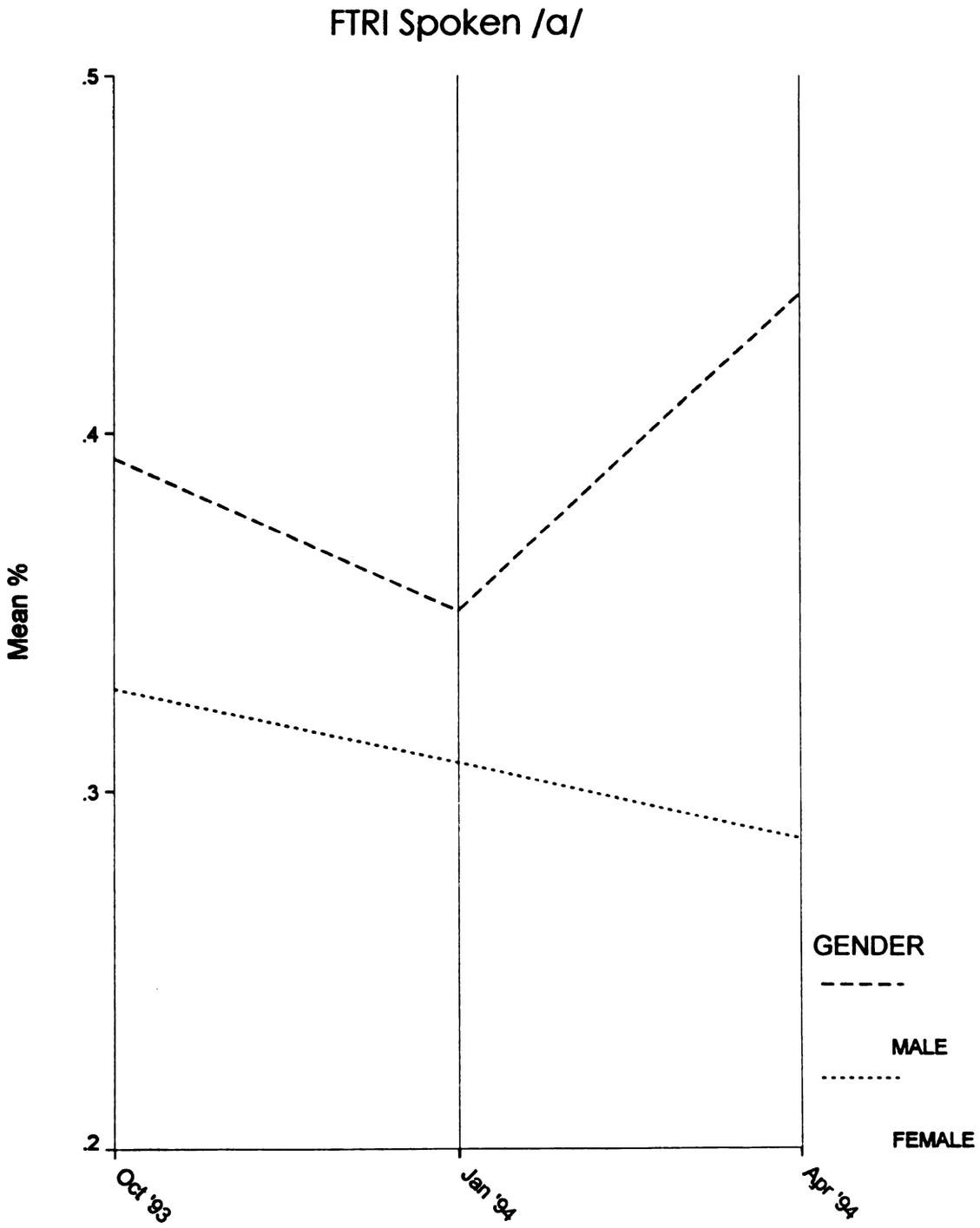

FTRI Spoken /a/
.5
.4
.3
.2
Mean %
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 16

APPENDIX K.2

ATRI SPOKEN /a/

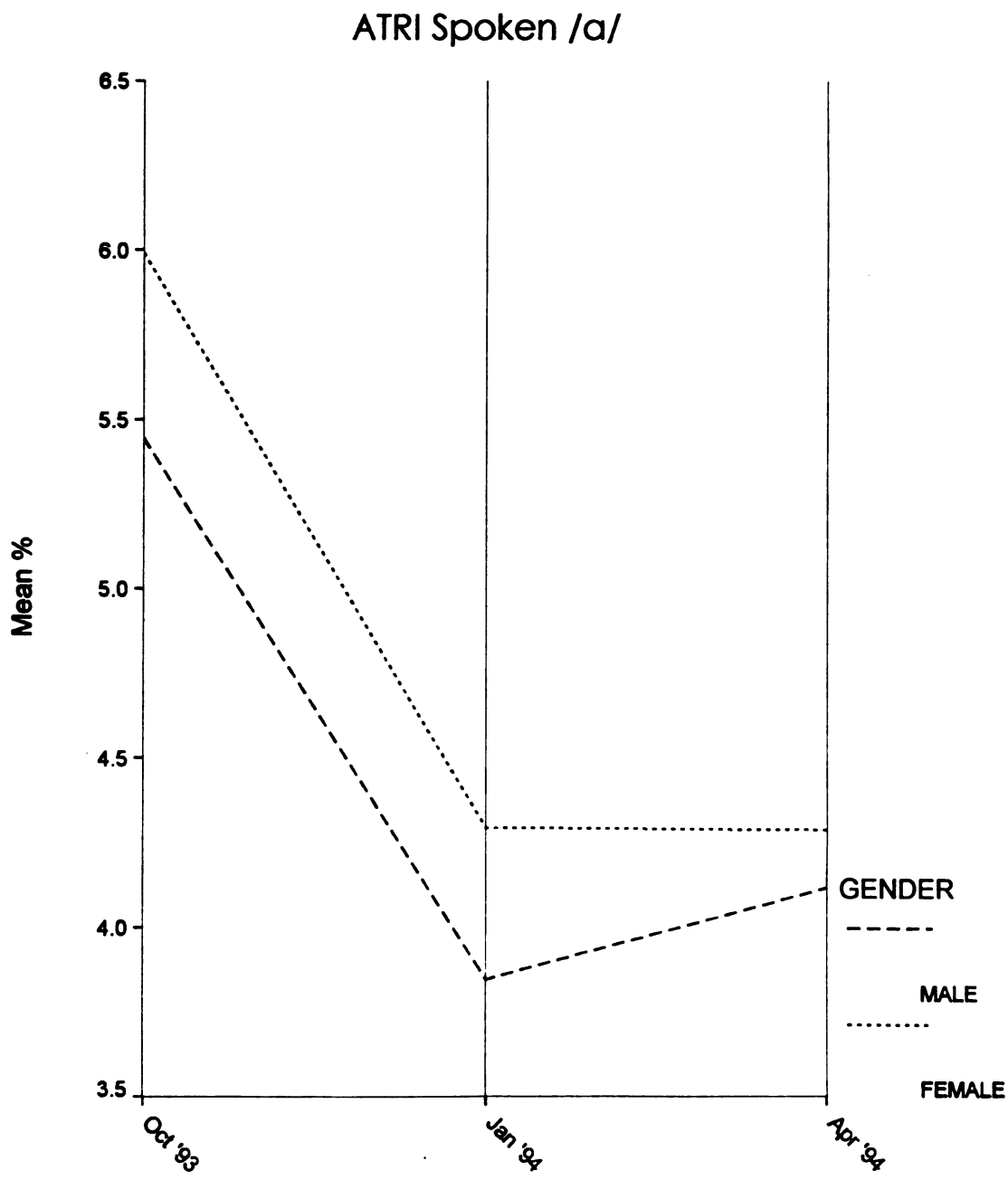

ATRI Spoken /a/
Mean %
6.5
6.0
5.5
5.0
4.5
4.0
3.5
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 17

APPENDIX K.3

Fftr SPOKEN /ɑ/

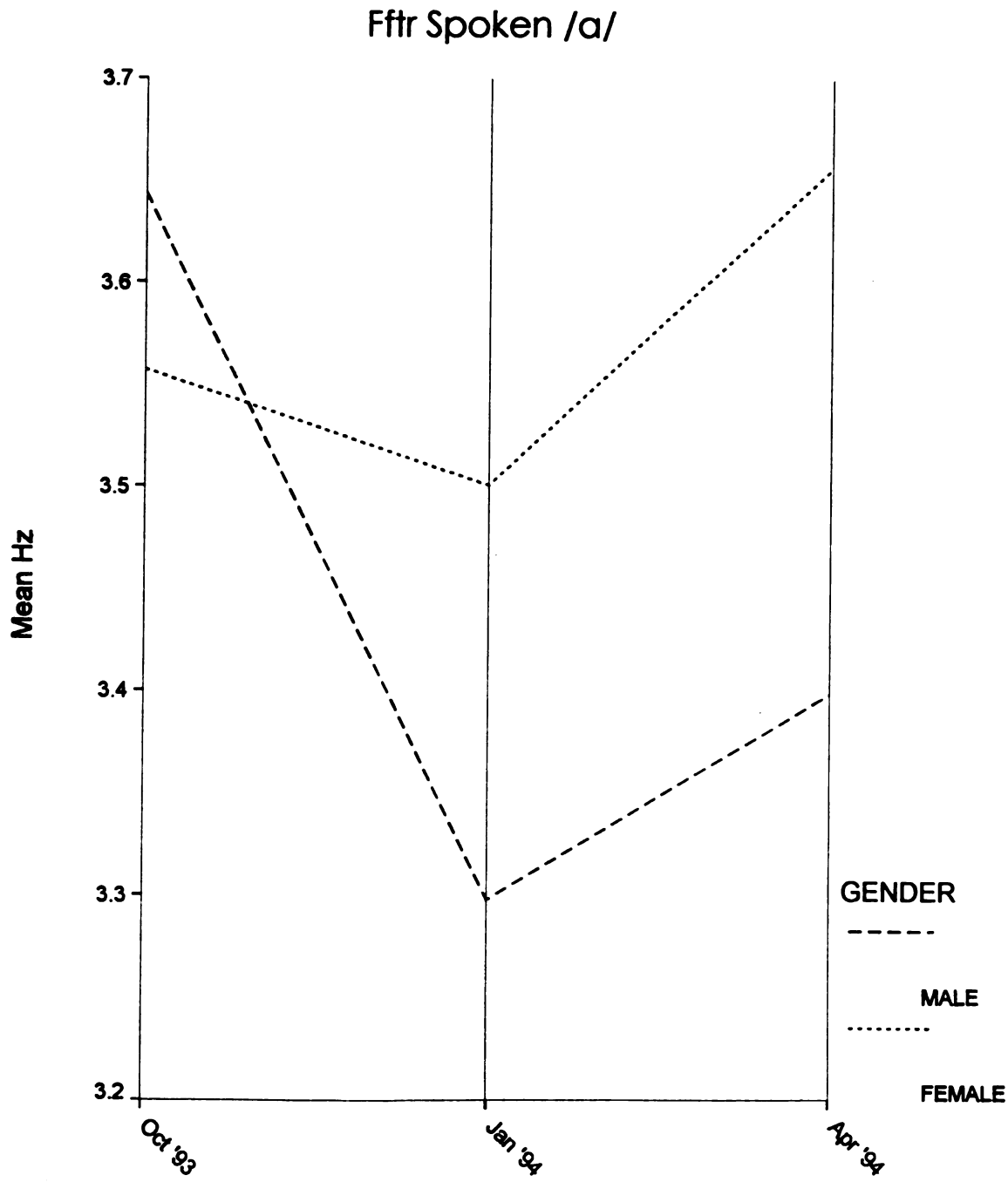

Fftr Spoken /a/
3.7
3.6
3.5
3.4
3.3
3.2
Mean Hz
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 18

APPENDIX K.4

Fatr SPOKEN /ɑ/

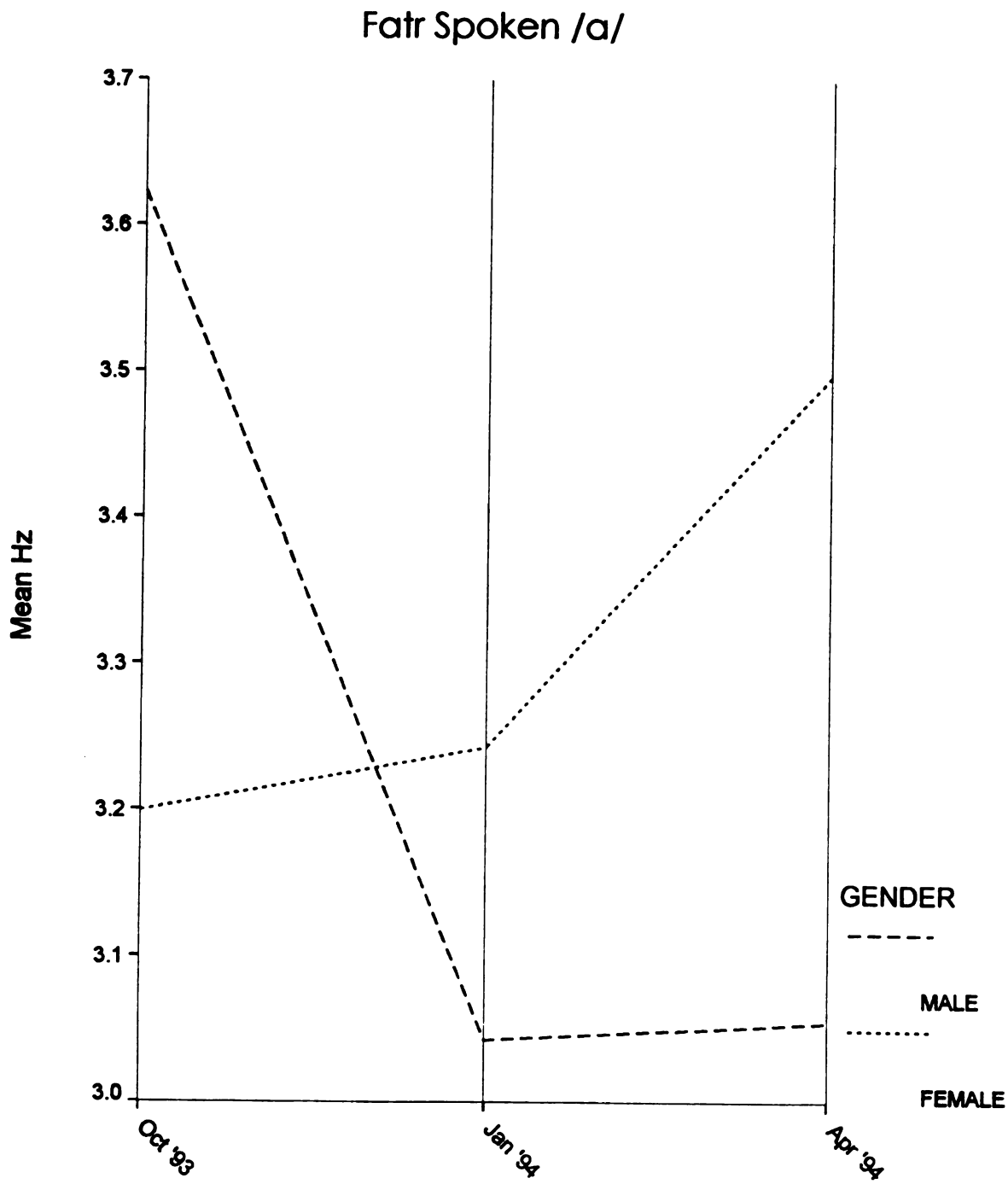

Fatr Spoken /a/
Mean Hz
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3.0
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 19

APPENDIX L.1

Fo SUNG /a/

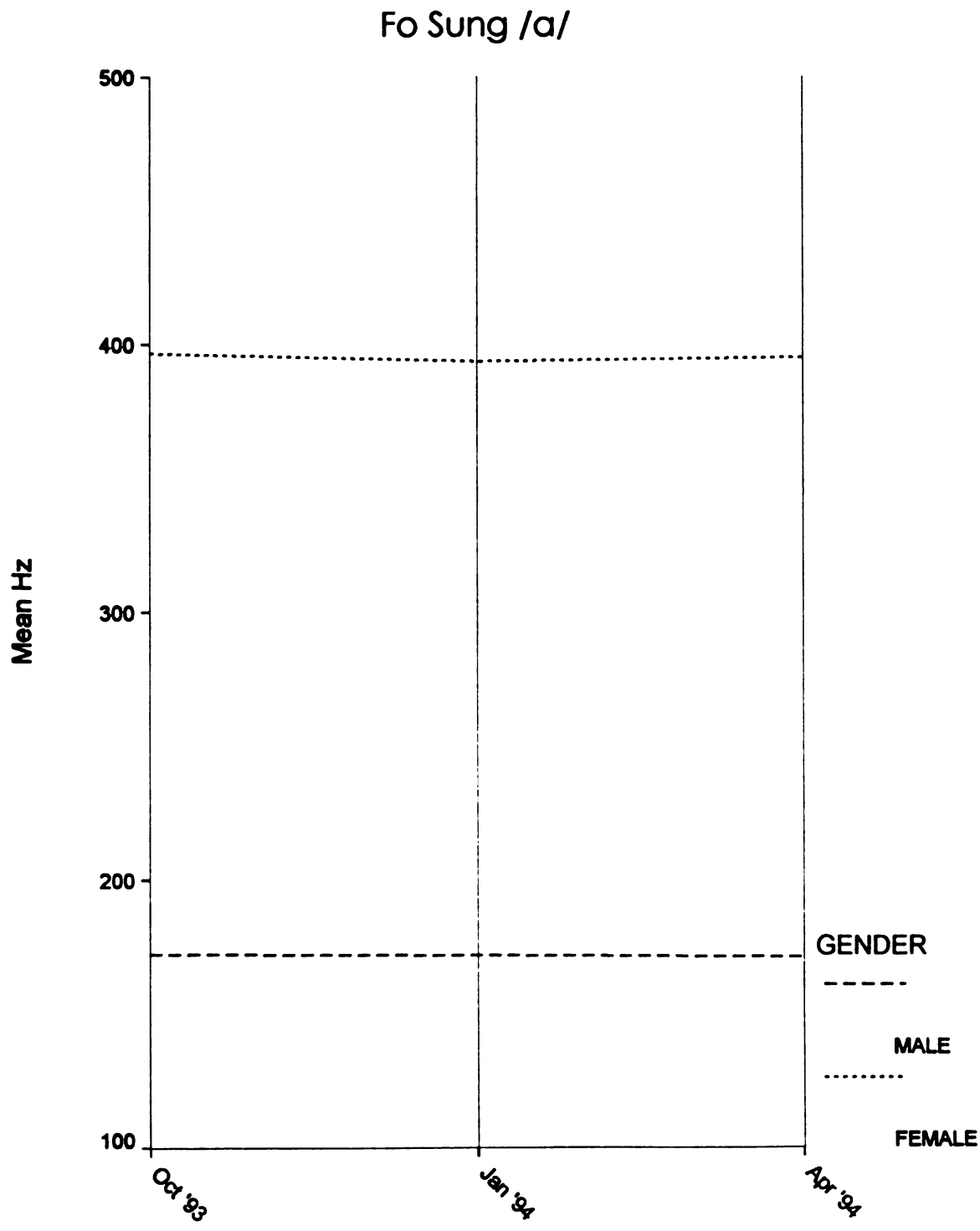

Fo Sung /a/
500
400
300
200
100
Mean Hz
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 20

APPENDIX L.2

Jita SUNG /ɑ/

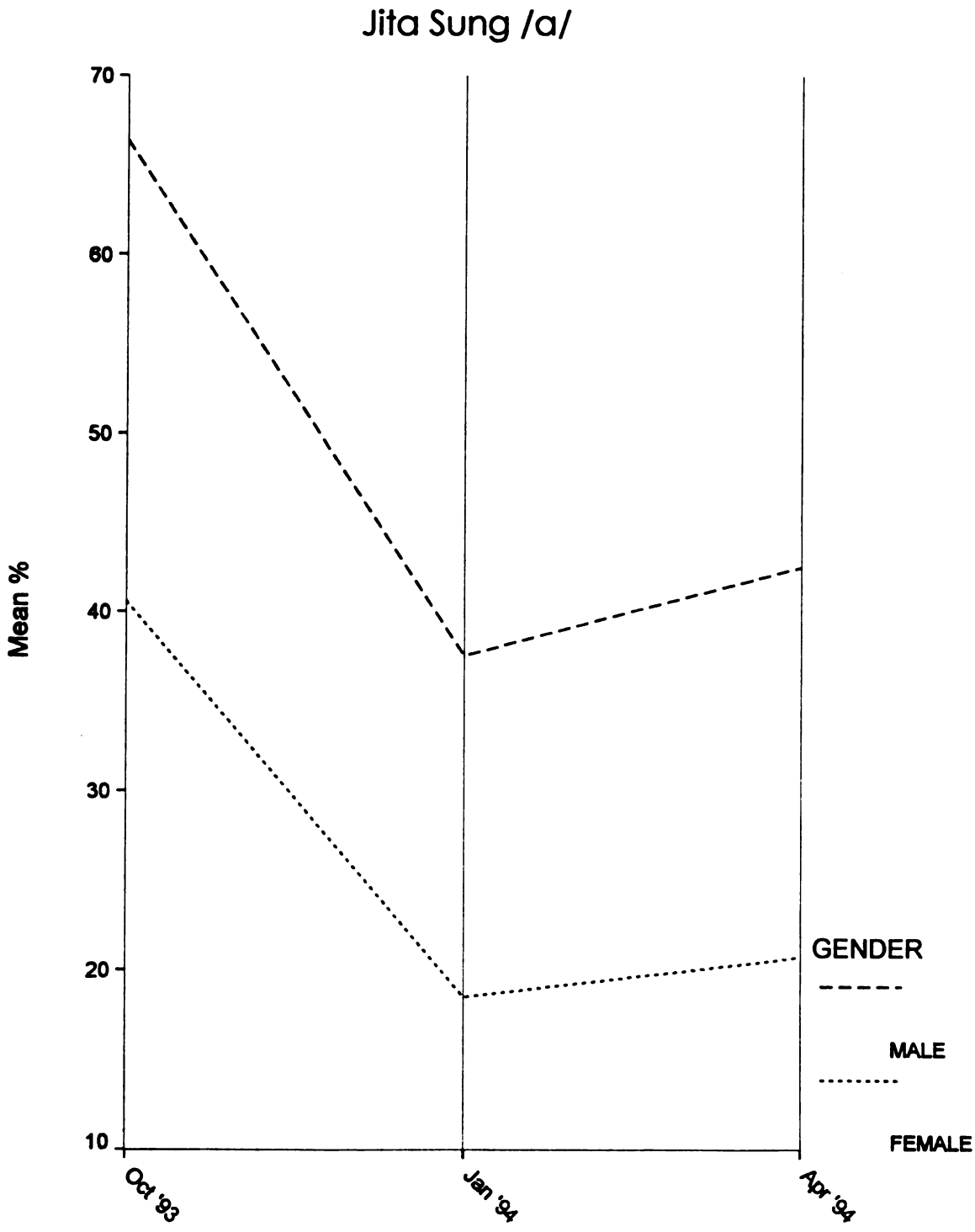

Jita Sung /a/
70
60
50
40
30
20
10
Mean %
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 21

APPENDIX L.3

Jitt SUNG /ɑ/

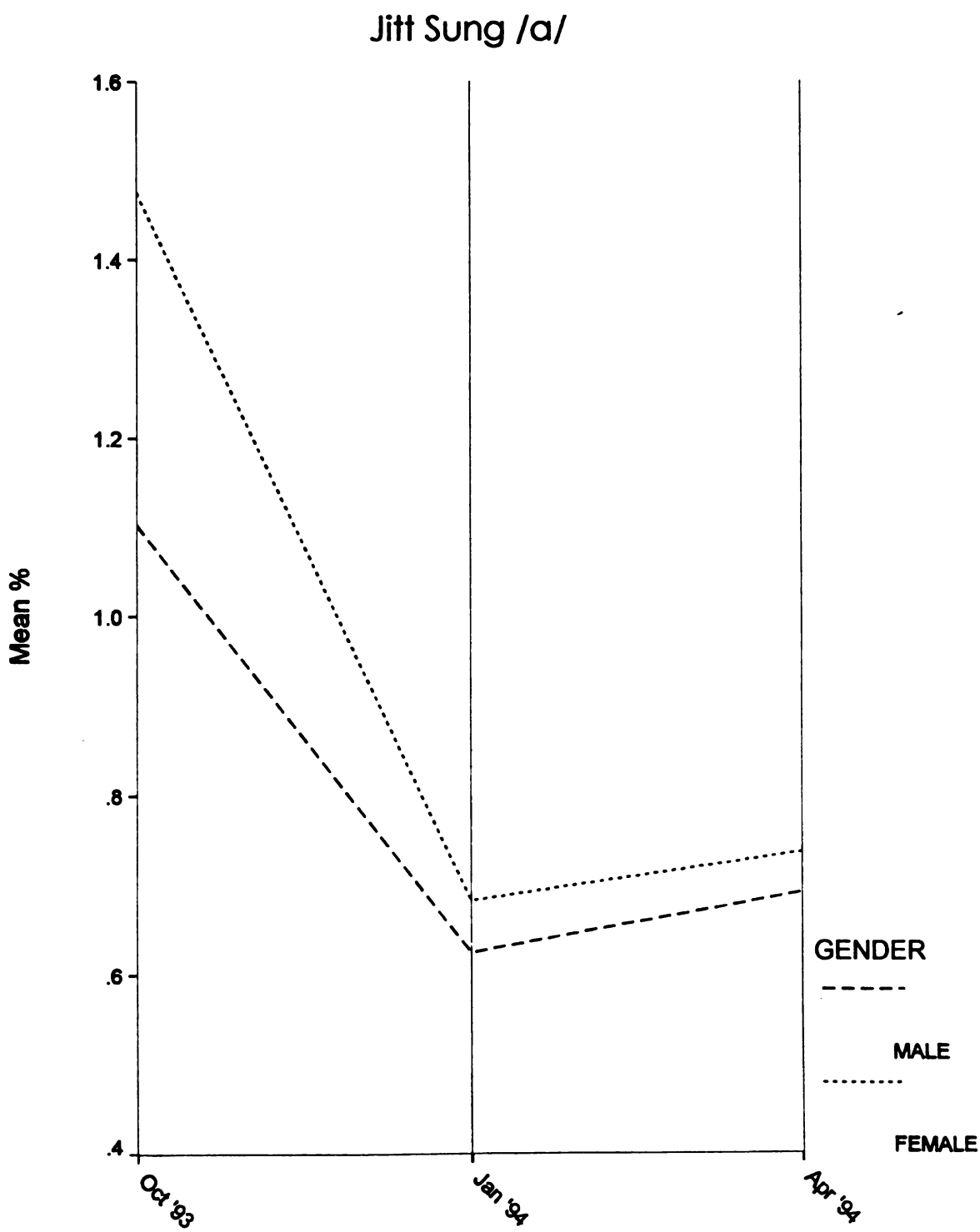

Jitt Sung /a/
Mean %
1.6
1.4
1.2
1.0
.8
.6
.4
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 22

APPENDIX L.4

RAP SUNG /a/

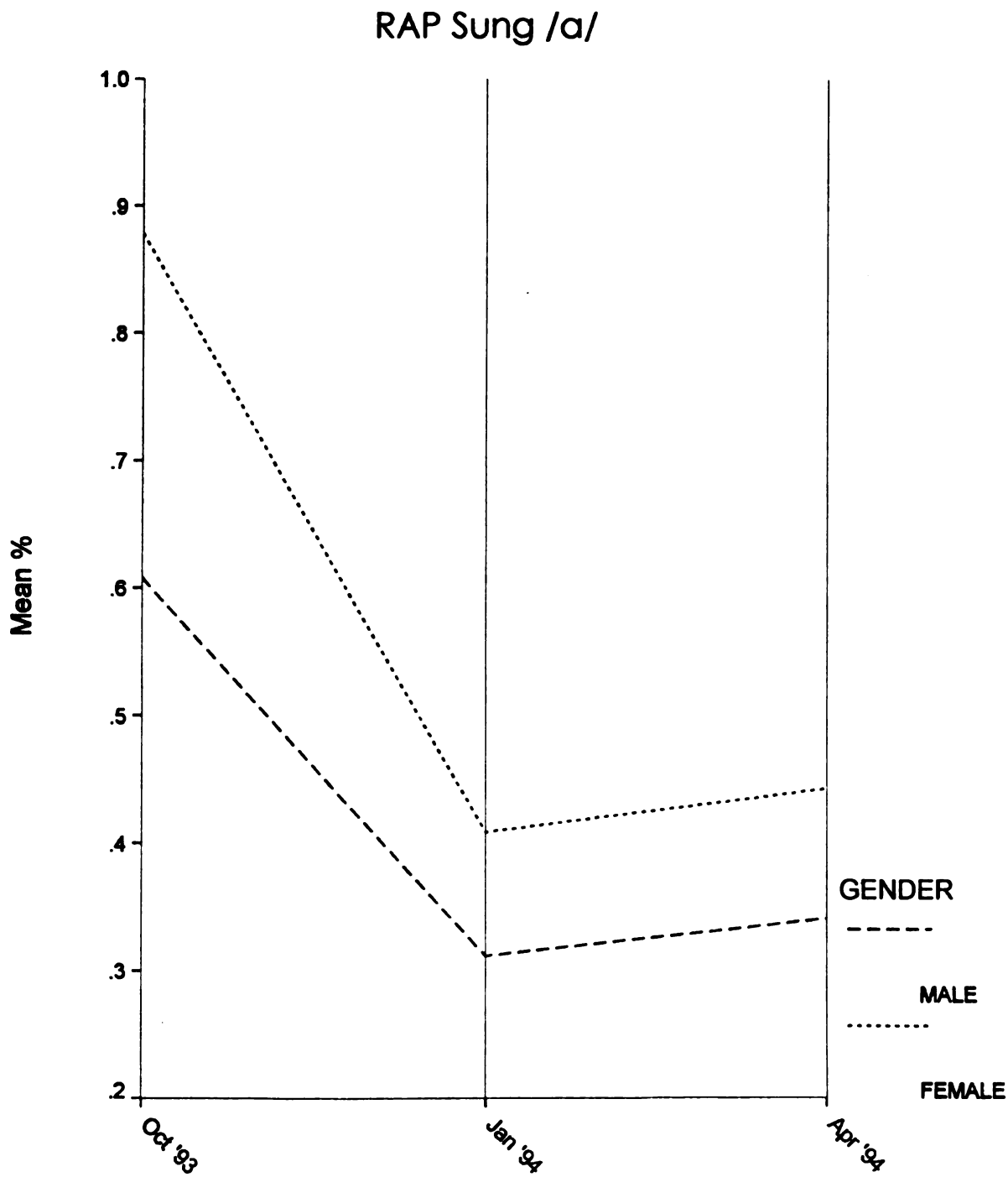

RAP Sung /a/
1.0
.9
.8
.7
.6
.5
.4
.3
.2
Mean %
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 23

APPENDIX L.5

PPQ SUNG /a/

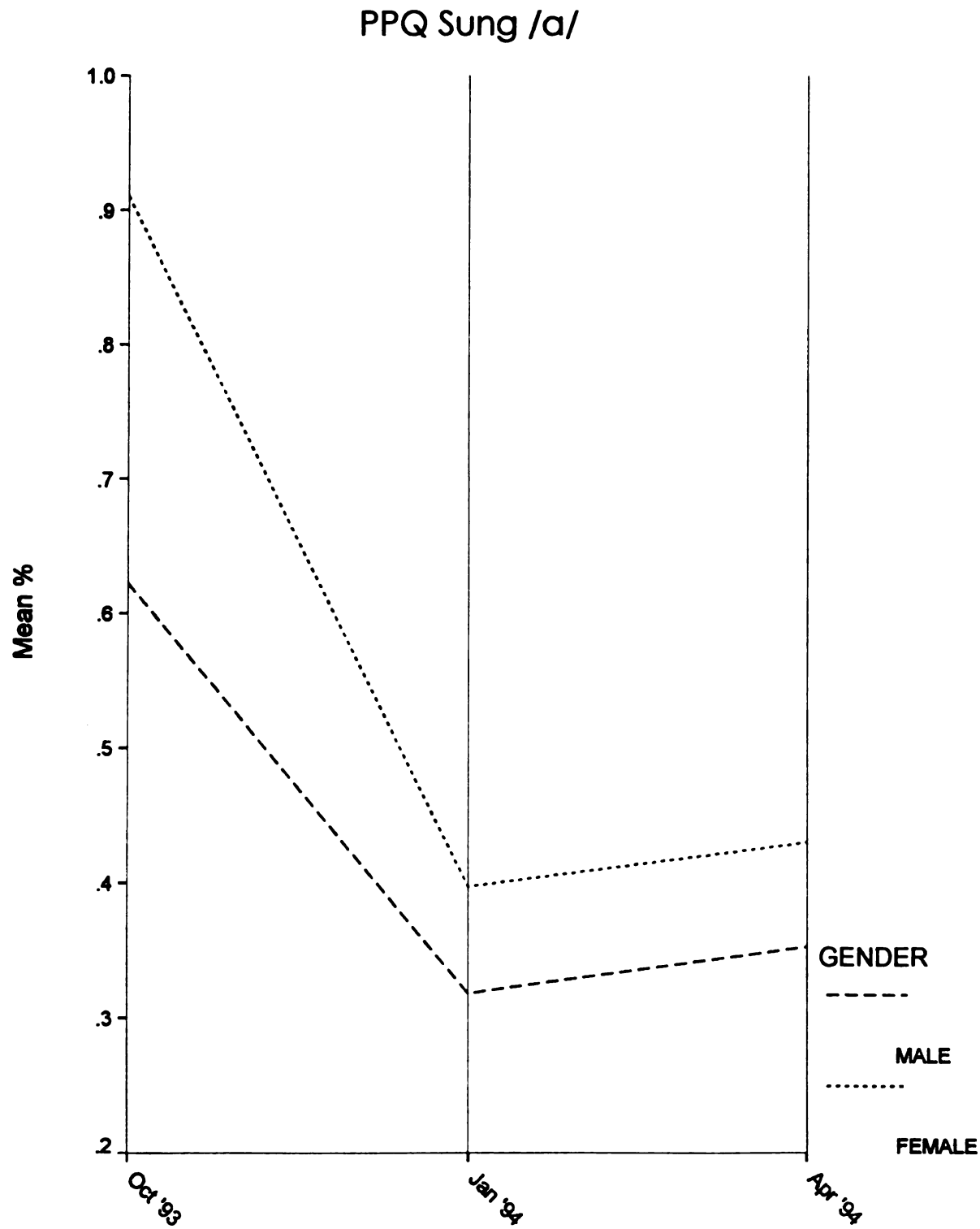

PPQ Sung /a/
1.0
.9
.8
.7
.6
.5
.4
.3
.2
Mean %
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 24

APPENDIX L.6

sPPQ SUNG /ɑ/

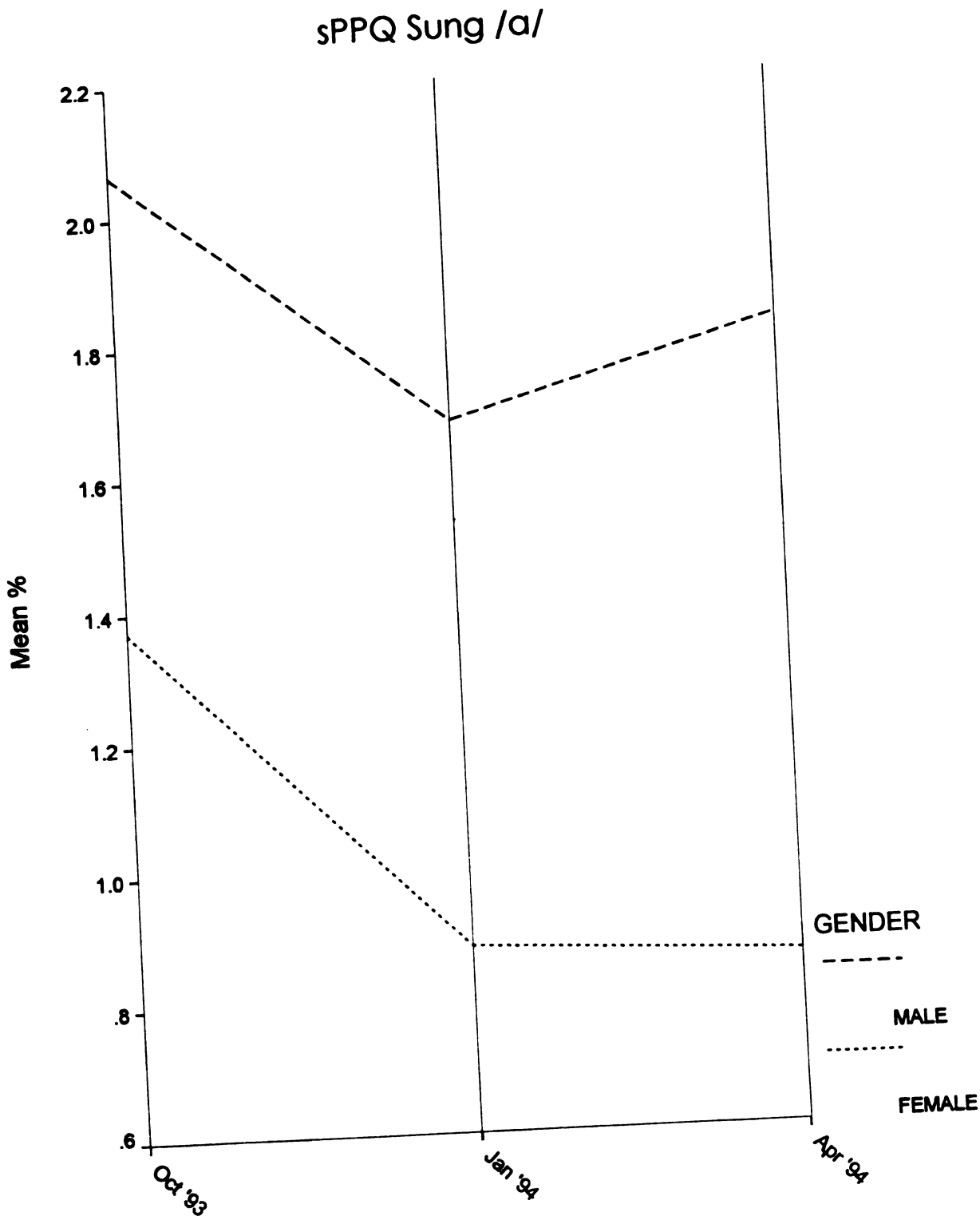

sPPQ Sung /a/
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
Mean %
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 25

APPENDIX L.7

vFo SUNG /a/

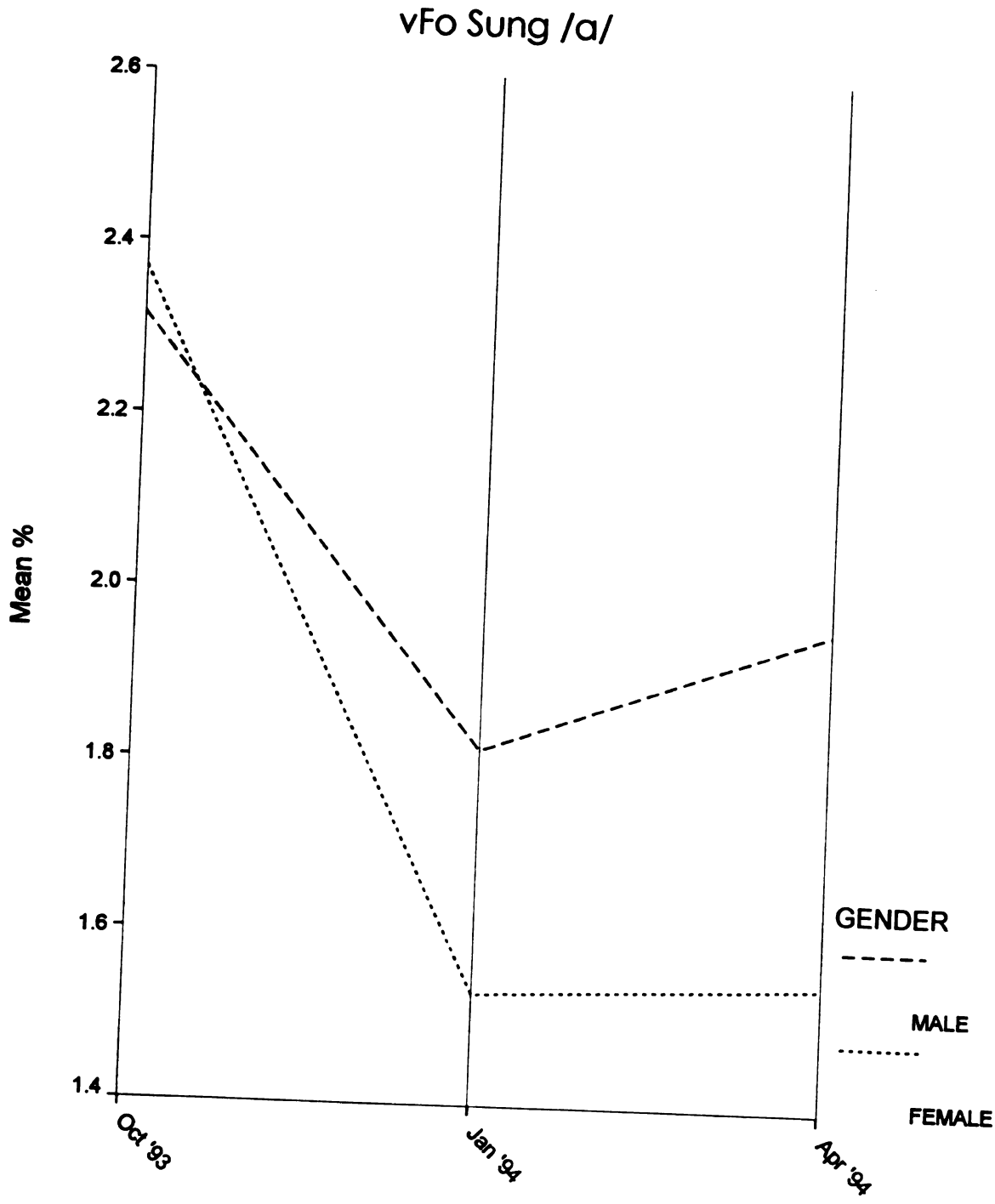

vFo Sung /a/
2.6
2.4
2.2
2.0
1.8
1.6
1.4
Mean %
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 26

APPENDIX M.1

ShdB SUNG /ɑ/

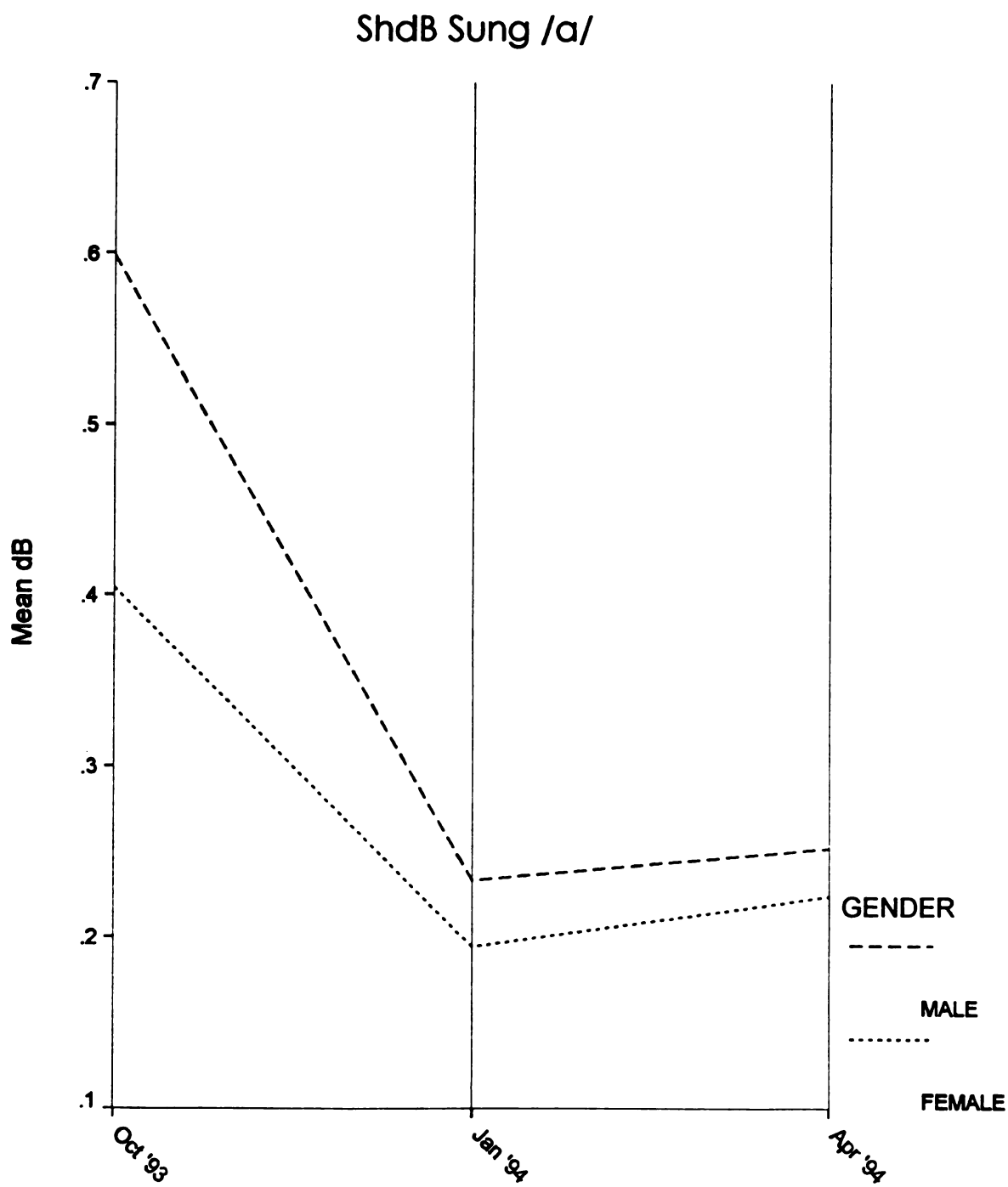

ShdB Sung /a/
Mean dB
.7
.6
.5
.4
.3
.2
.1
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 27

APPENDIX M.2

Shim SUNG /ɑ/

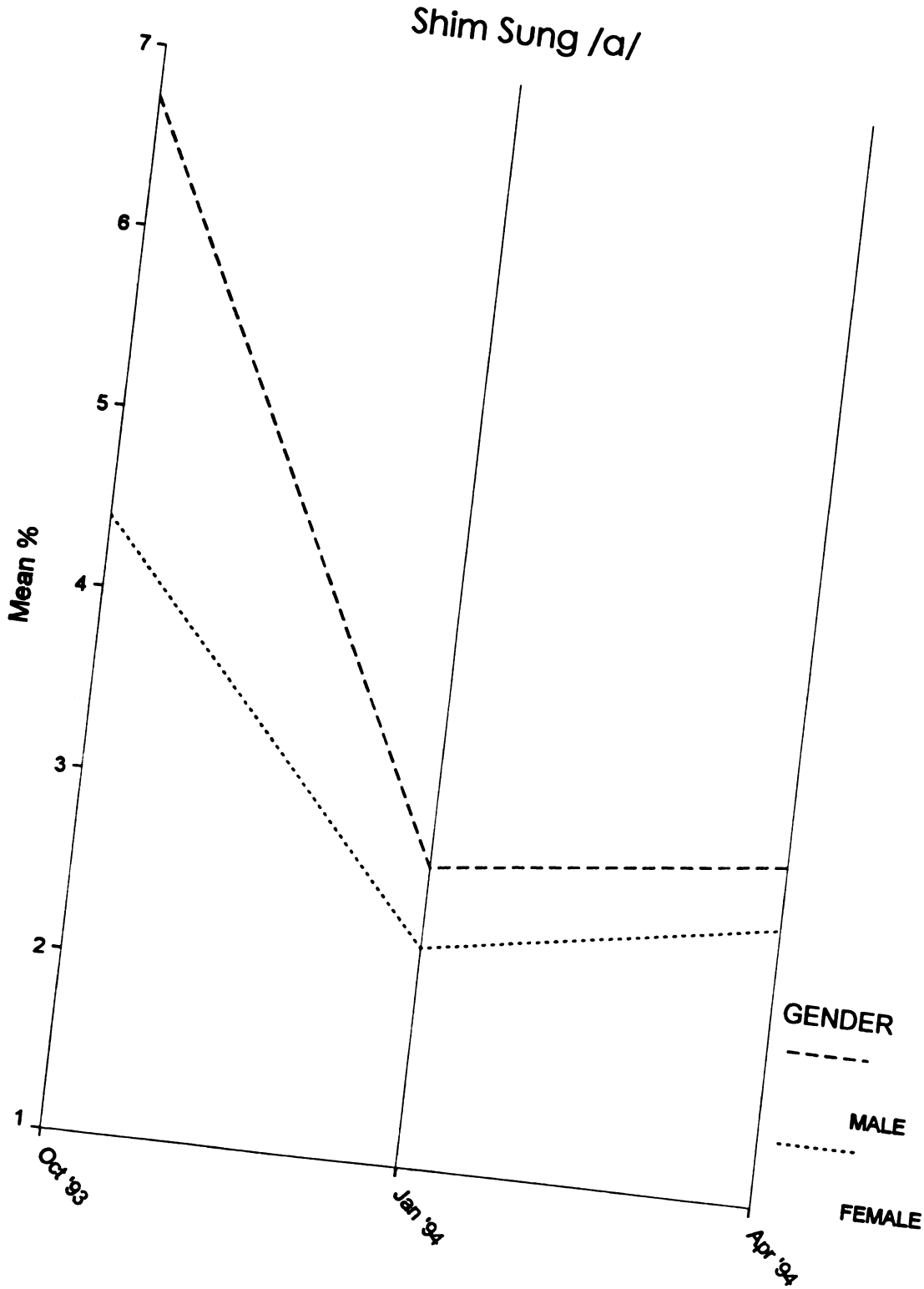

Shim Sung /a/
7
6
5
4
3
2
1
Mean %
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 28

APPENDIX M.3

APQ_SUNG /ɑ/

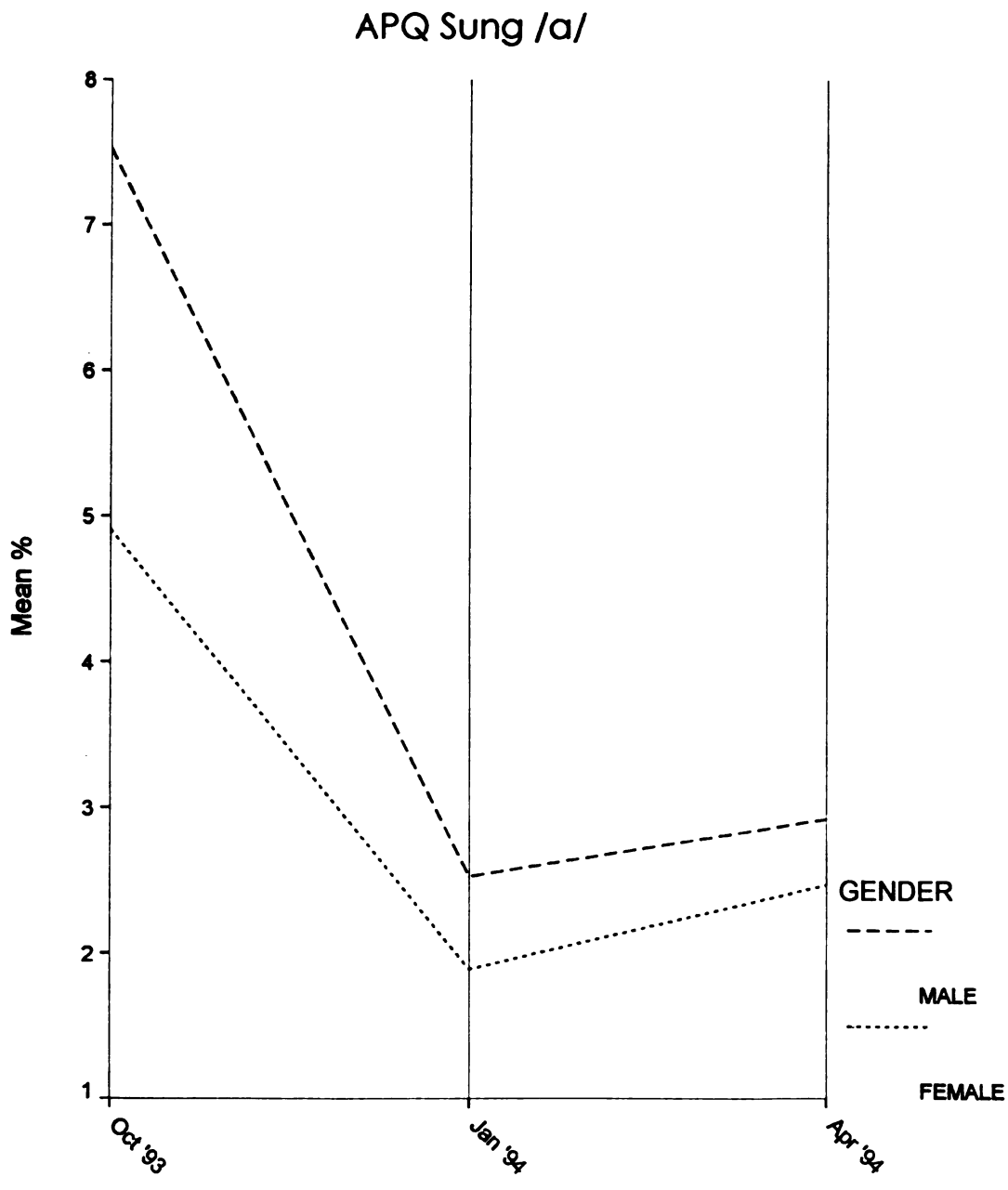

APQ Sung /a/
Mean %
8
7
6
5
4
3
2
1
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 29

APPENDIX M.4

sAPQ SUNG /ɑ/

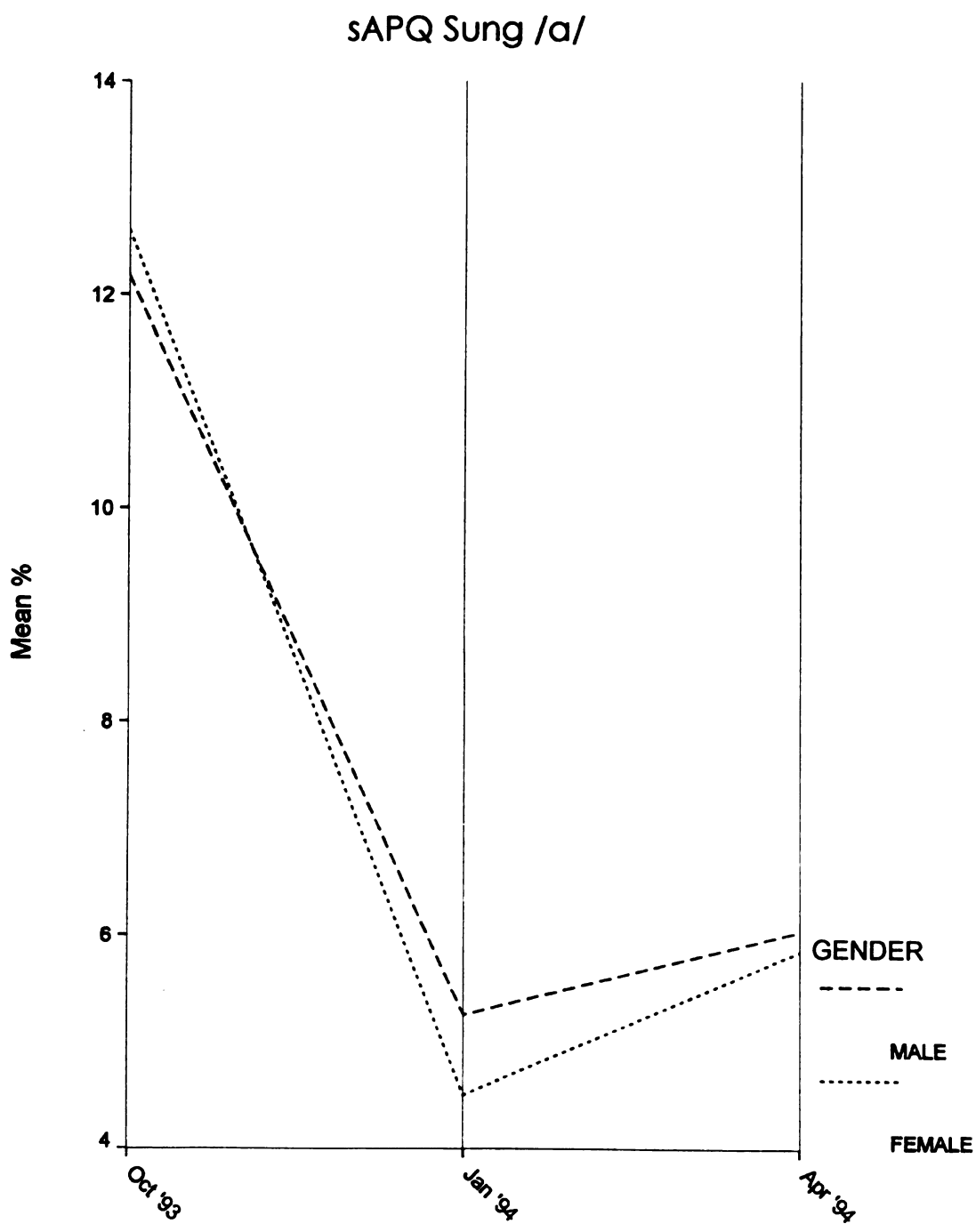

sAPQ Sung /a/
14
12
10
8
6
4
Mean %
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 30

APPENDIX M.5

vAm SUNG /ɑ/

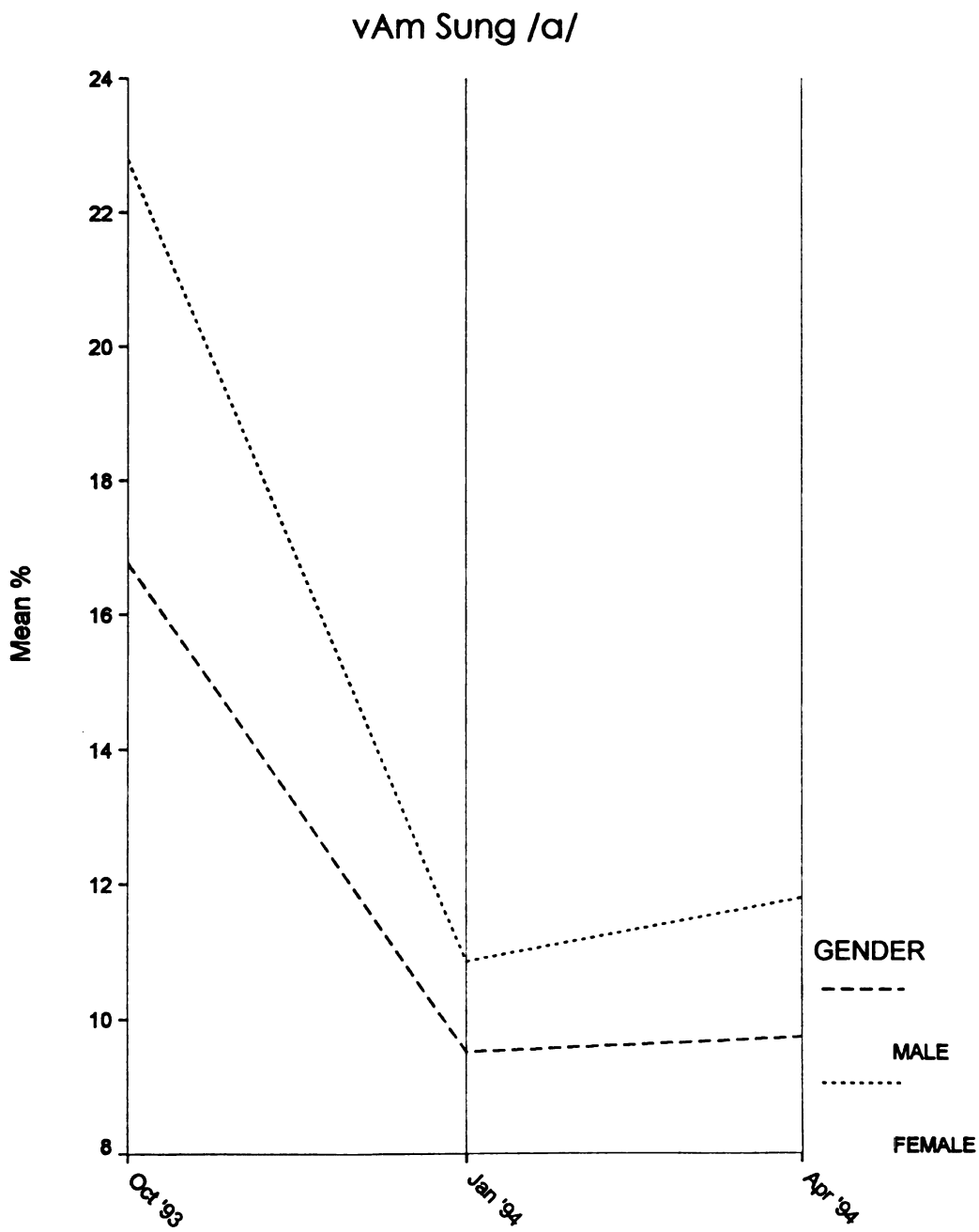

vAm Sung /a/
24
22
20
18
16
14
12
10
8
Mean %
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 31

APPENDIX N.1

NHR SUNG /ɑ/

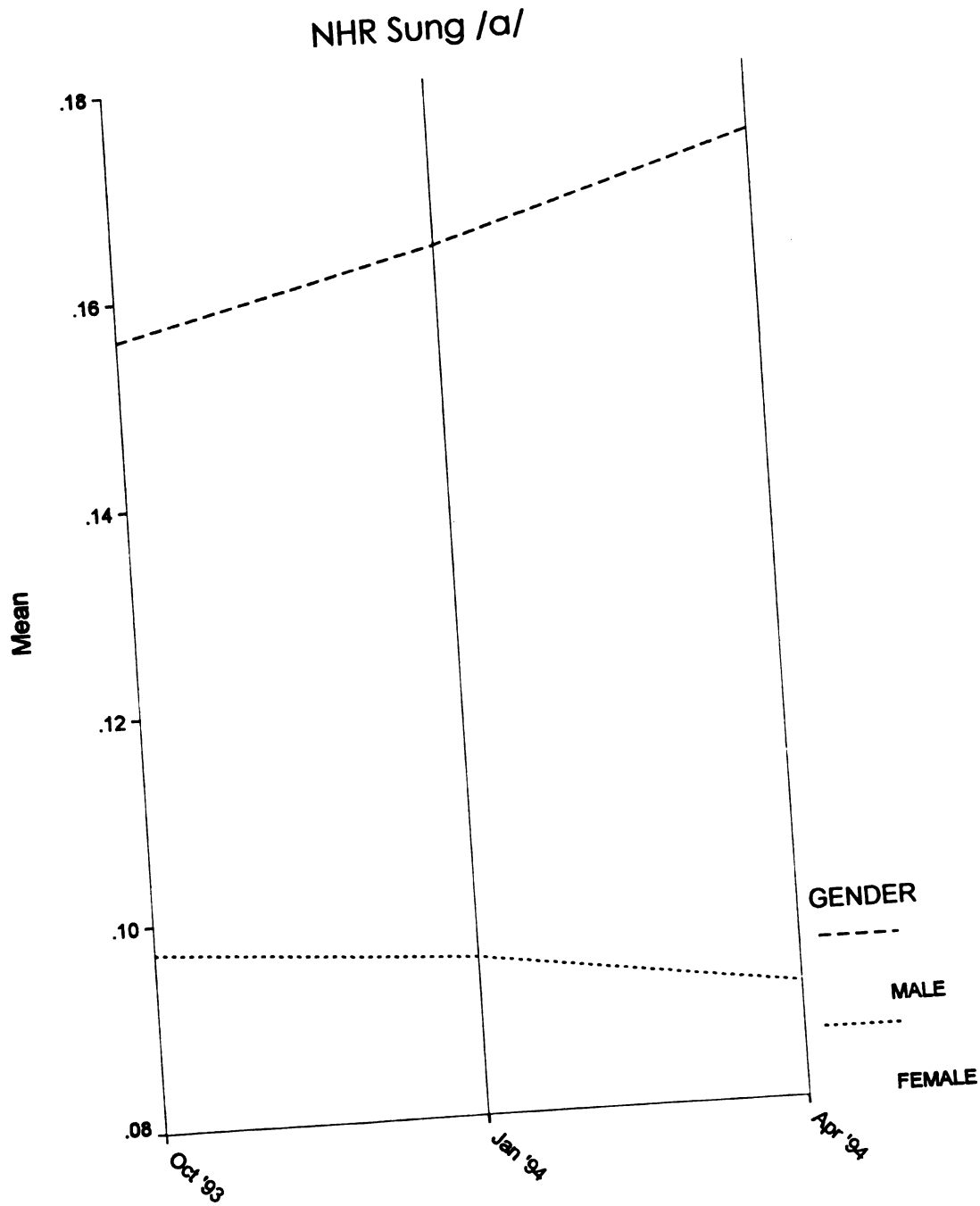

NHR Sung /a/
.18
.16
.14
.12
.10
.08
Mean
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 32

APPENDIX N.2

VTI SUNG /a/

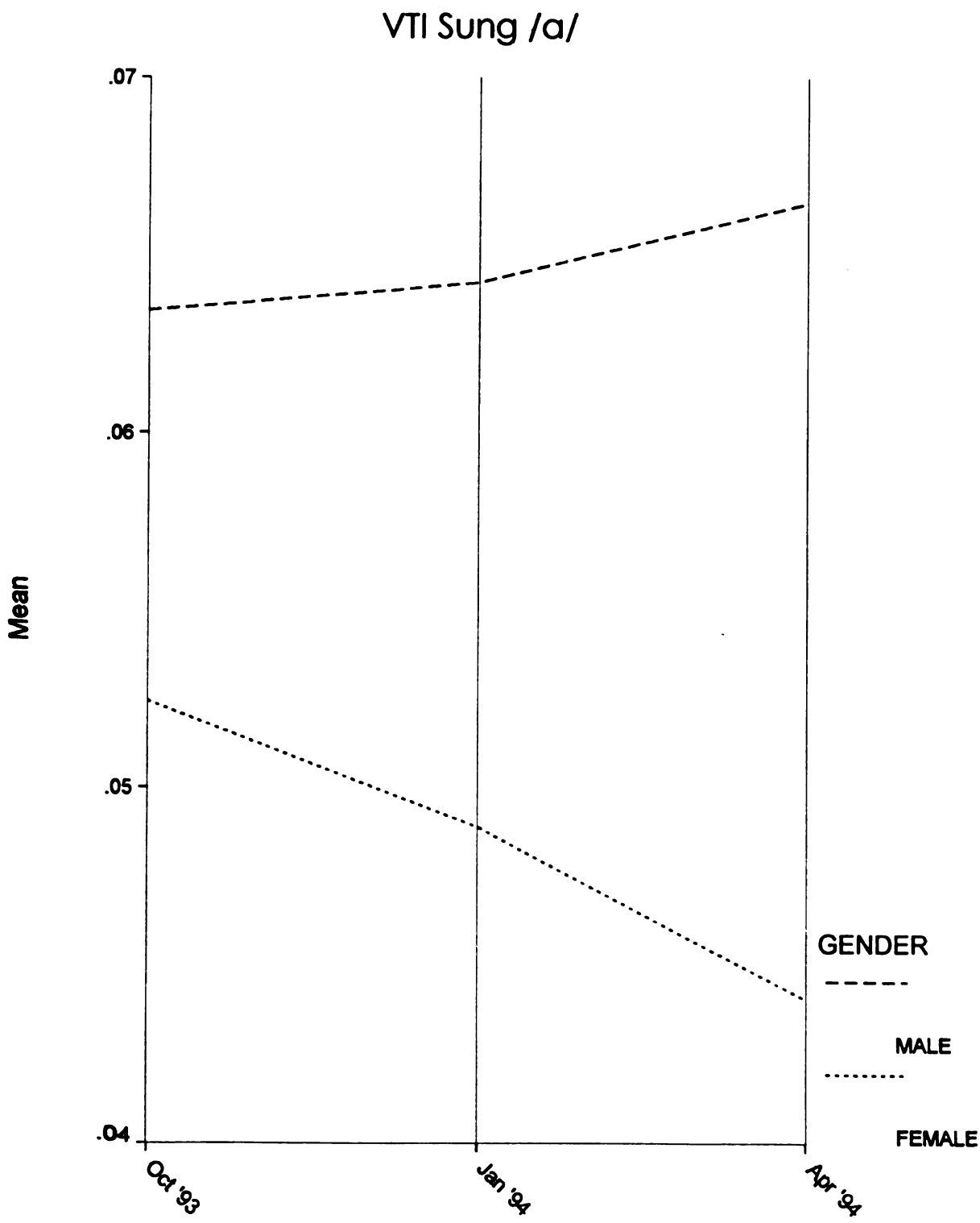

VTI Sung /a/
.07
.06
.05
.04
Mean
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 33

APPENDIX N.3

SPI SUNG /a/

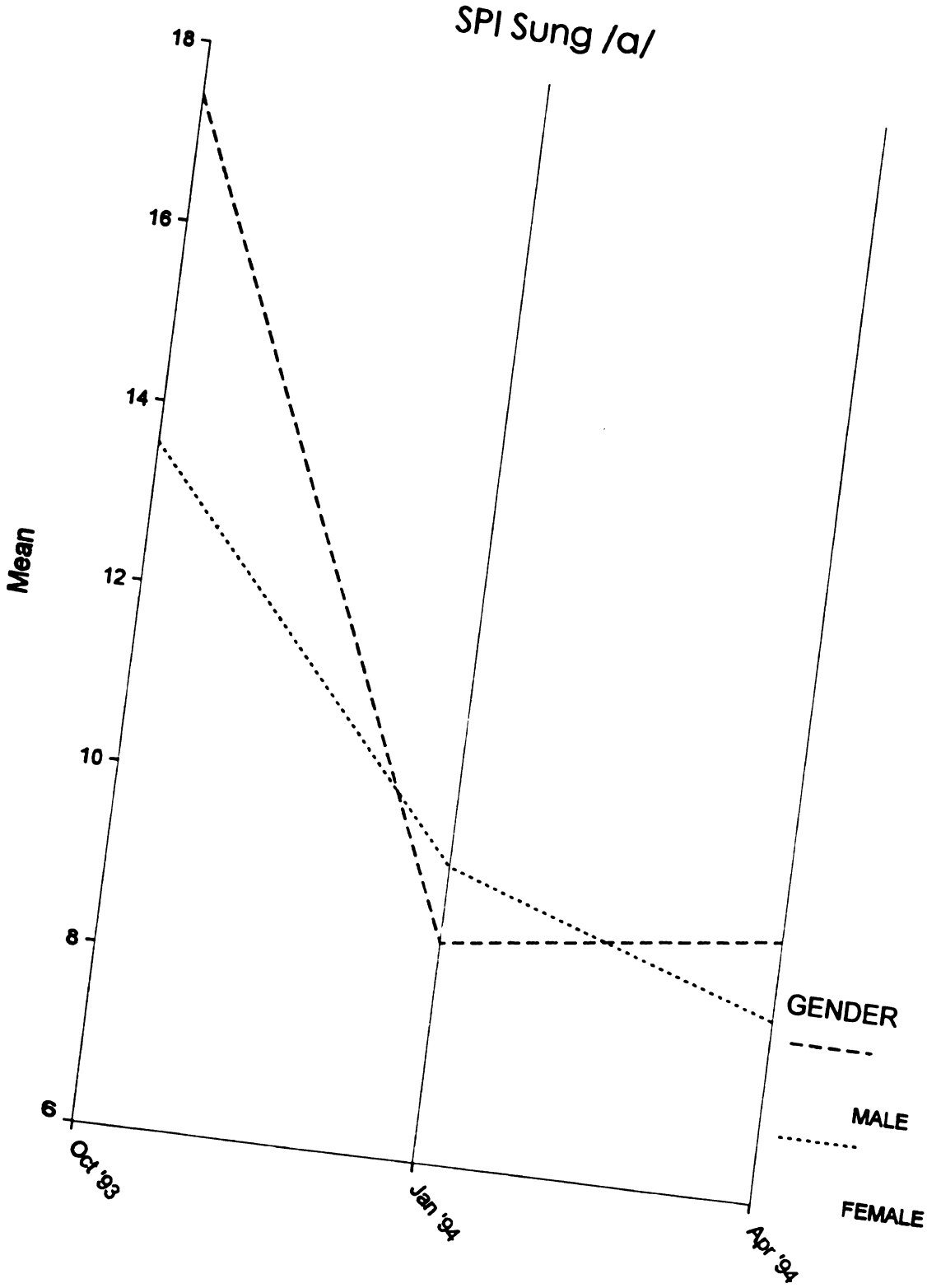

SPI Sung /a/
18
16
14
12
10
8
6
Mean
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 34

APPENDIX O.1

FTRI SUNG /a/

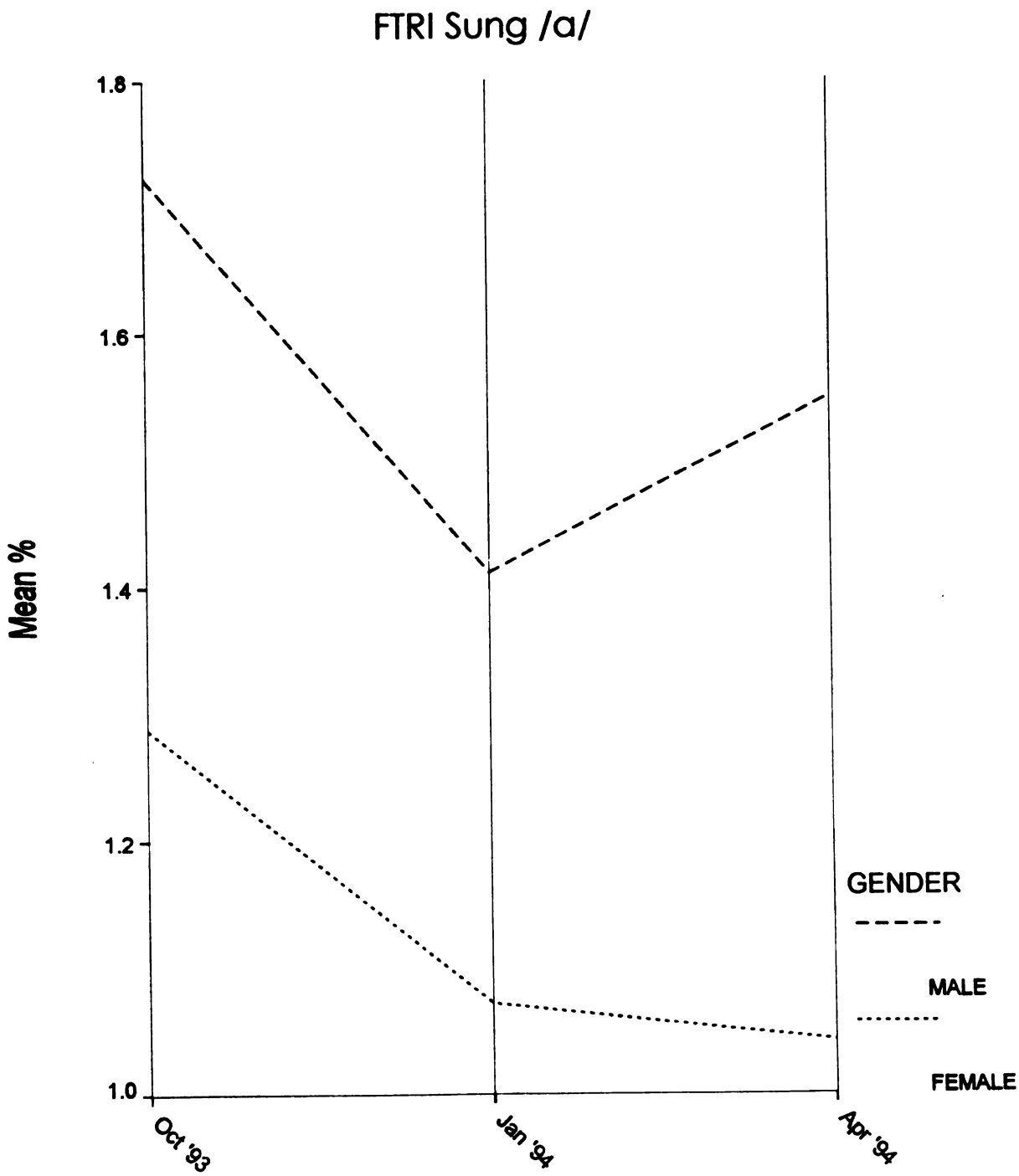

FTRI Sung /a/
Mean %
1.8
1.6
1.4
1.2
1.0
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 35

APPENDIX O.2

ATRI SUNG /a/

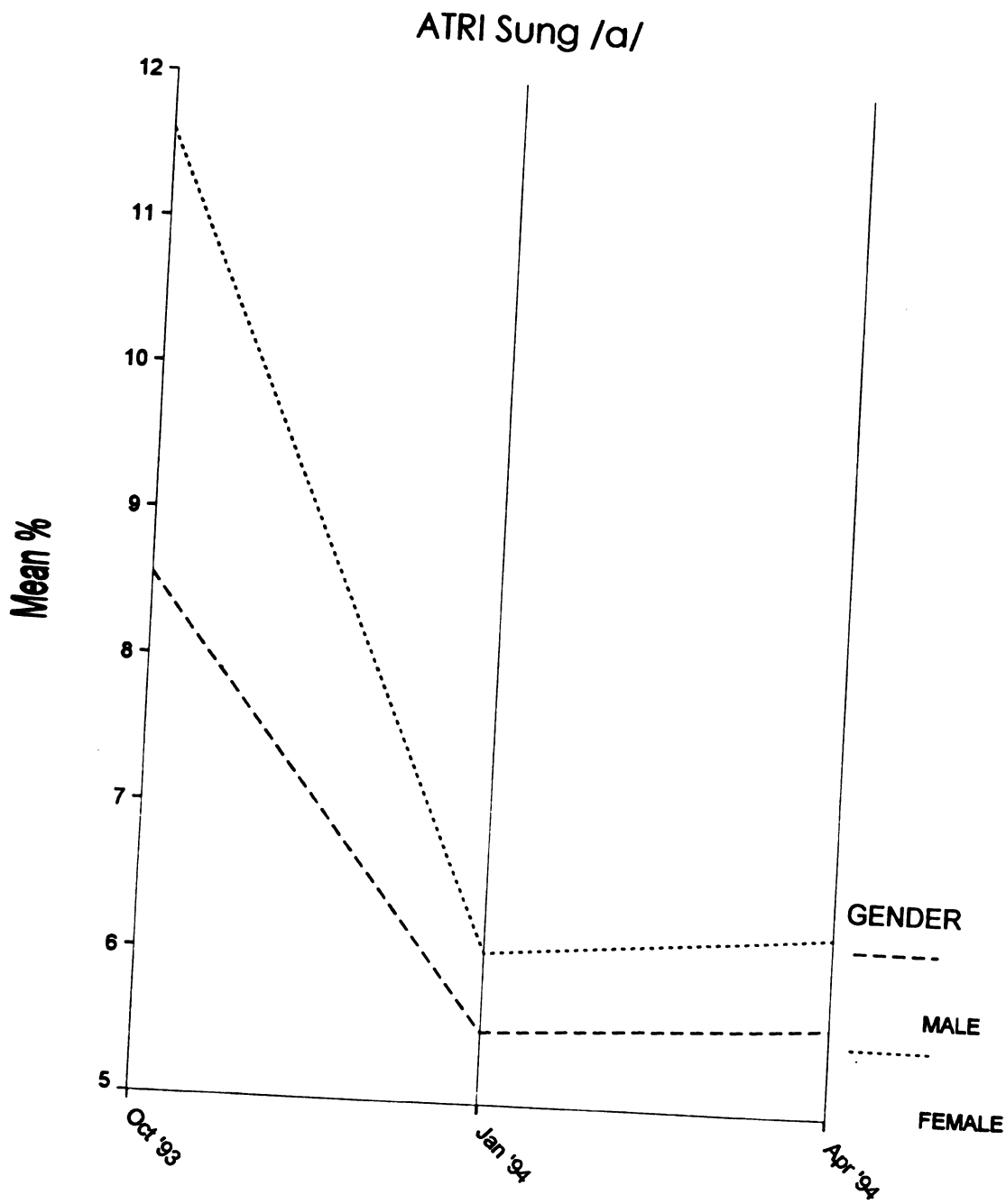

ATRI Sung /a/
Mean %
12
11
10
9
8
7
6
5
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 36

APPENDIX O.3

Fftr SUNG /ɑ/

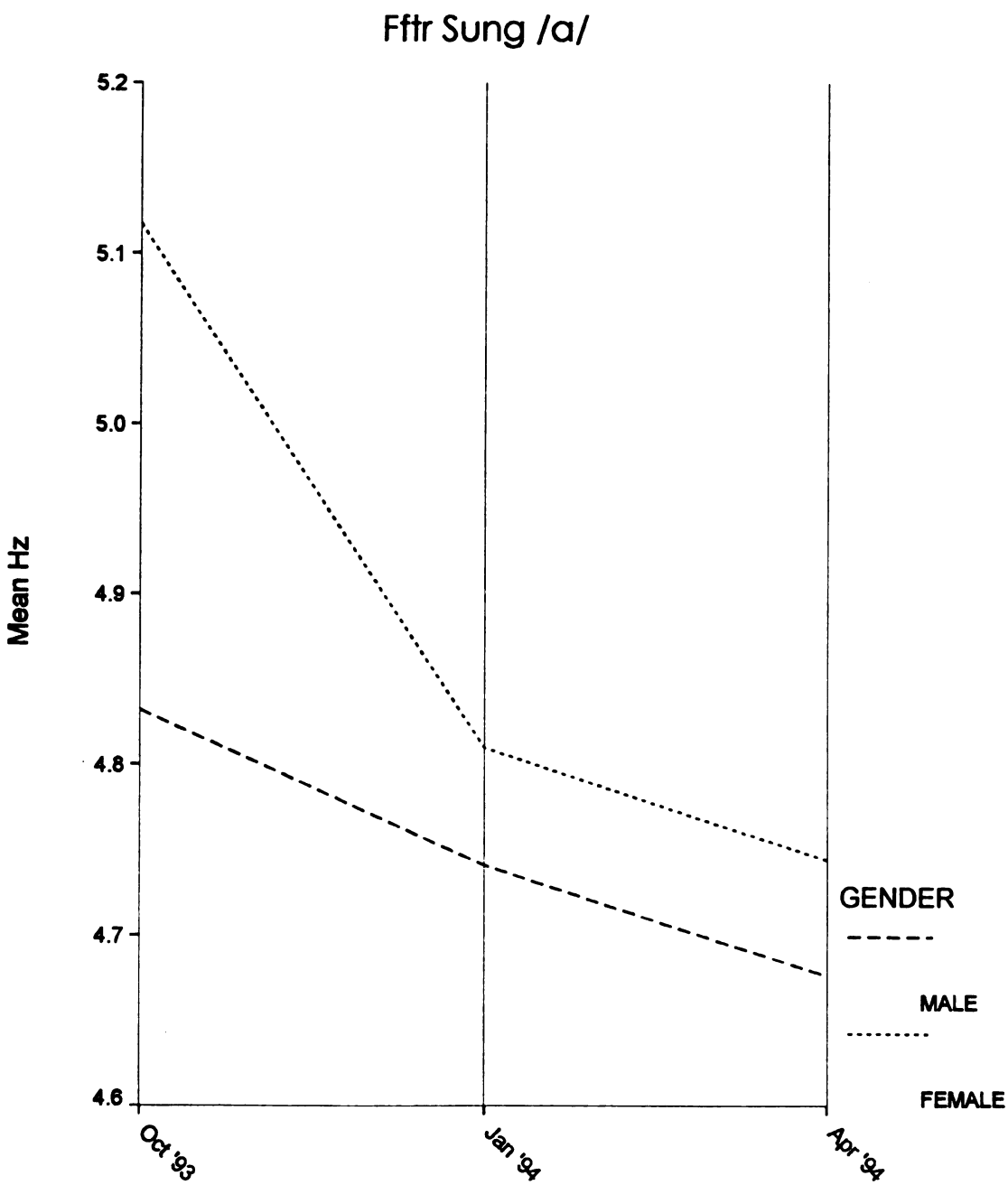

Fftr Sung /a/
Mean Hz
5.2
5.1
5.0
4.9
4.8
4.7
4.6
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 37

APPENDIX 0.4

Fatr SUNG /ɑ/

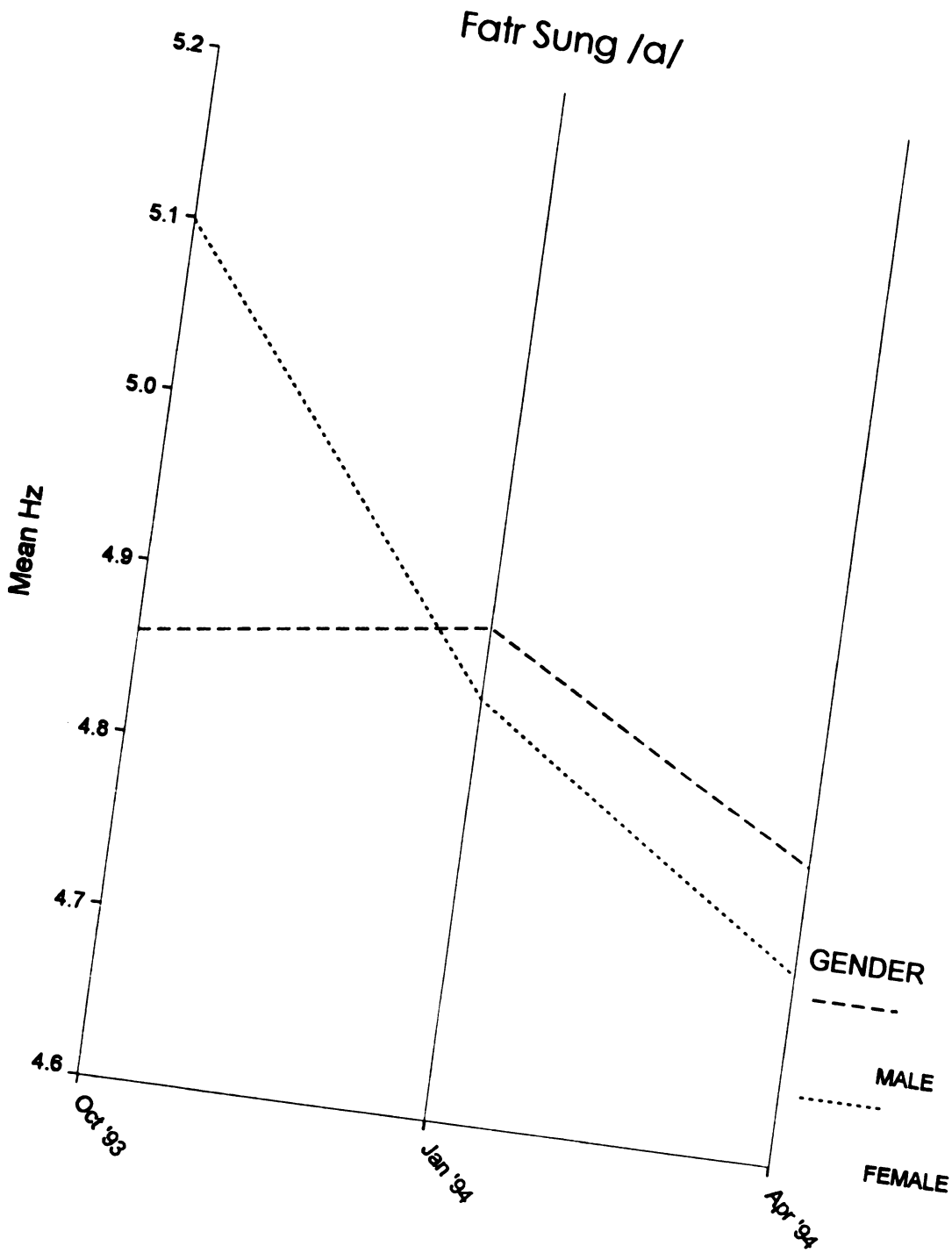

Fatr Sung /a/
5.2
5.1
5.0
4.9
4.8
4.7
4.6
Mean Hz
Oct '93
Jan '94
Apr '94
GENDER
MALE
FEMALE

FIGURE 38

APPENDIX P.1

Fo SPOKEN /i/

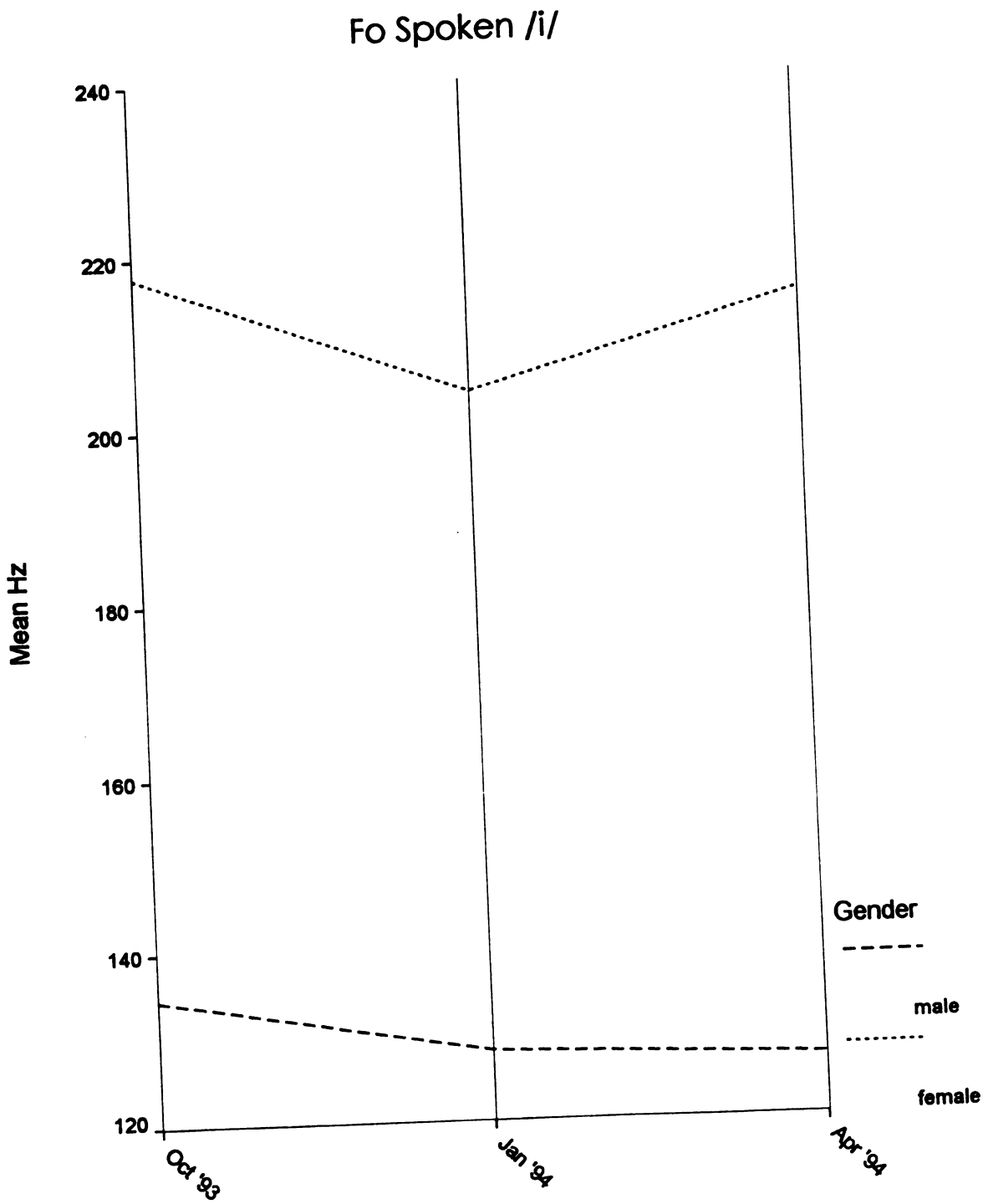

Fo Spoken /i/
240
220
200
180
160
140
120
Mean Hz
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 39

APPENDIX P.2

Jita SPOKEN /i/

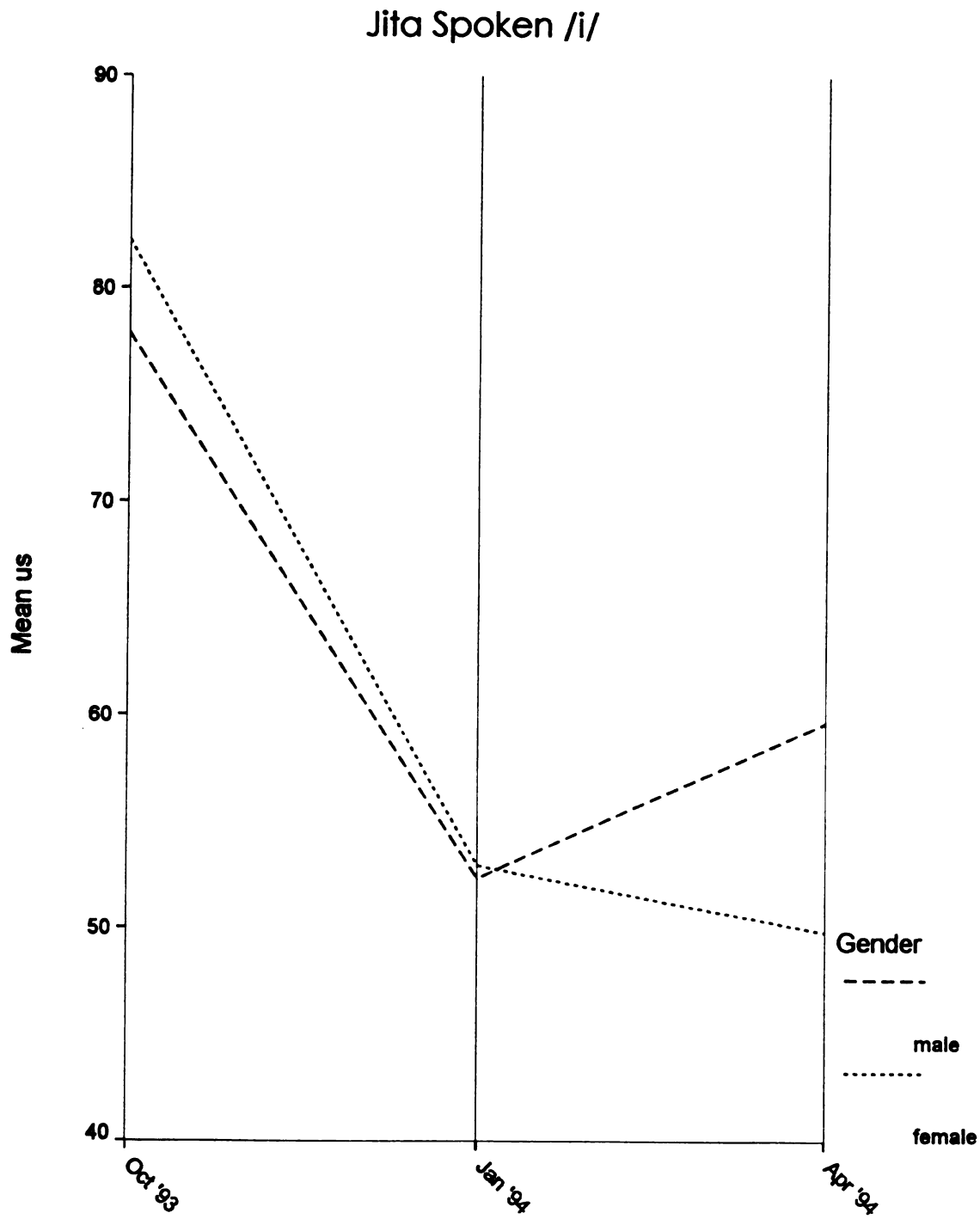

Jita Spoken /i/
90
80
70
60
50
40
Mean us
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 40

APPENDIX P.3

Jitt SPOKEN /i/

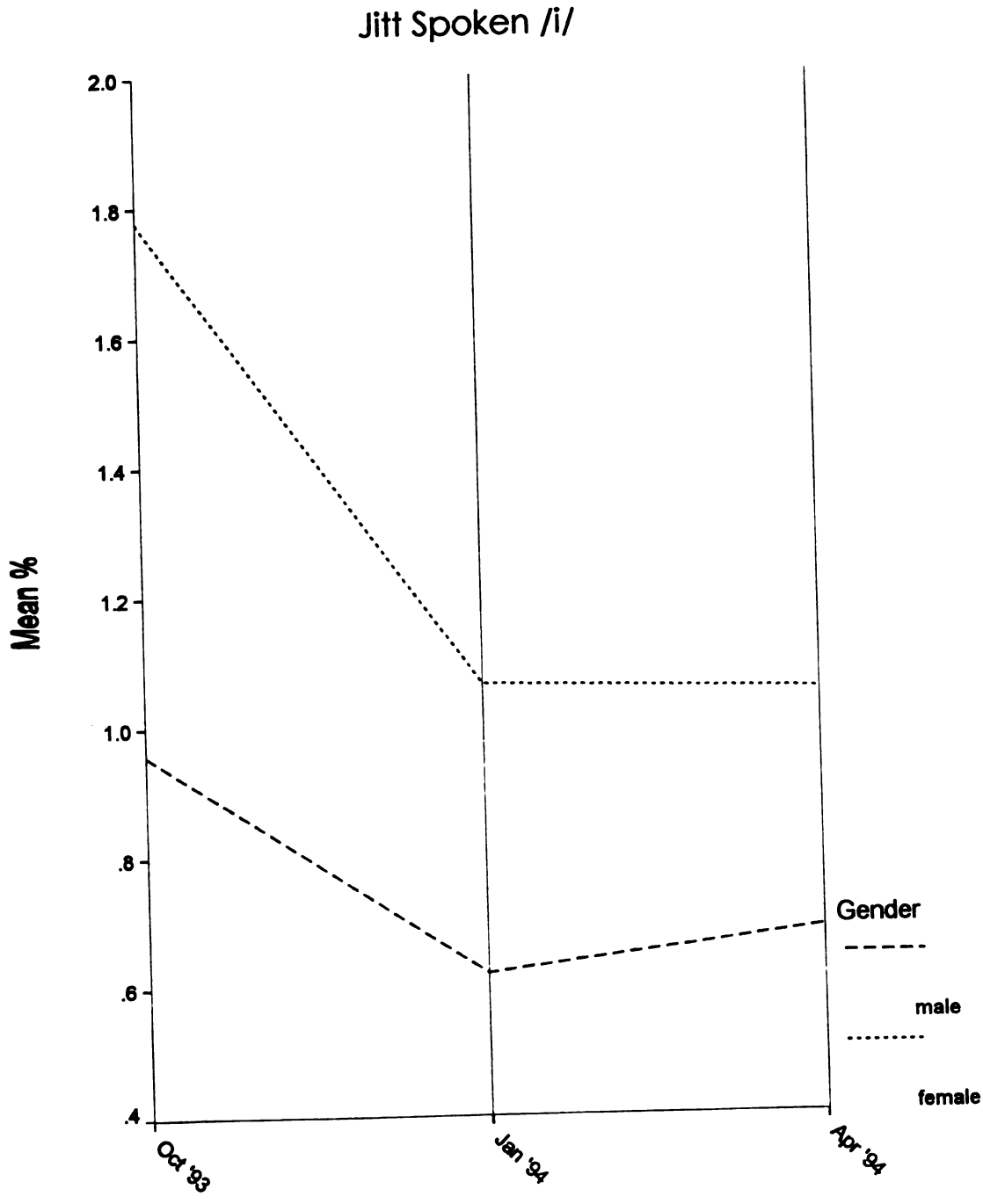

Jitt Spoken /i/
Mean %
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 41

APPENDIX P.4

RAP SPOKEN /i/

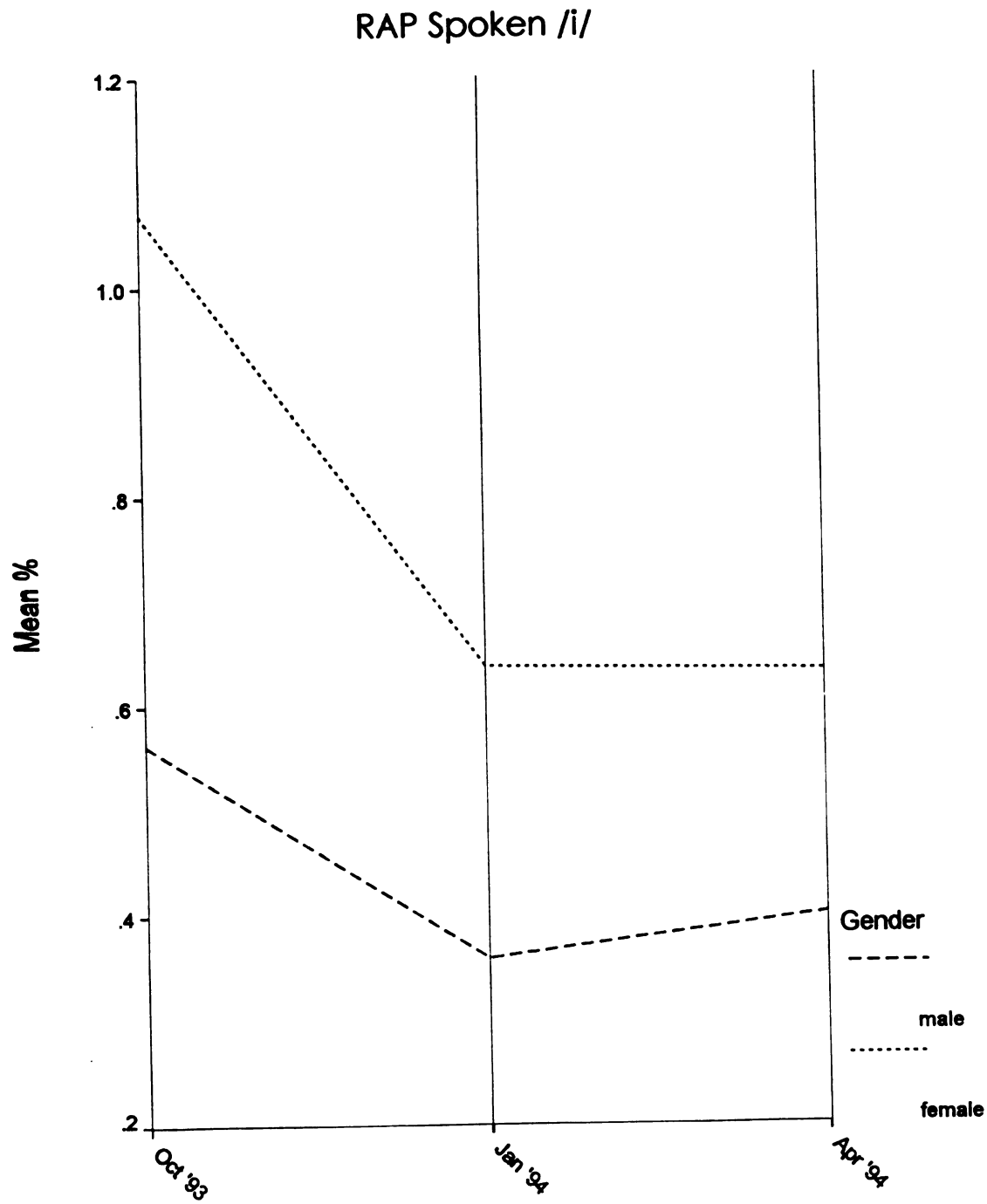

RAP Spoken /i/
1.2
1.0
.8
.6
.4
.2
Mean %
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 42

APPENDIX P.5

PPQ SPOKEN /i/

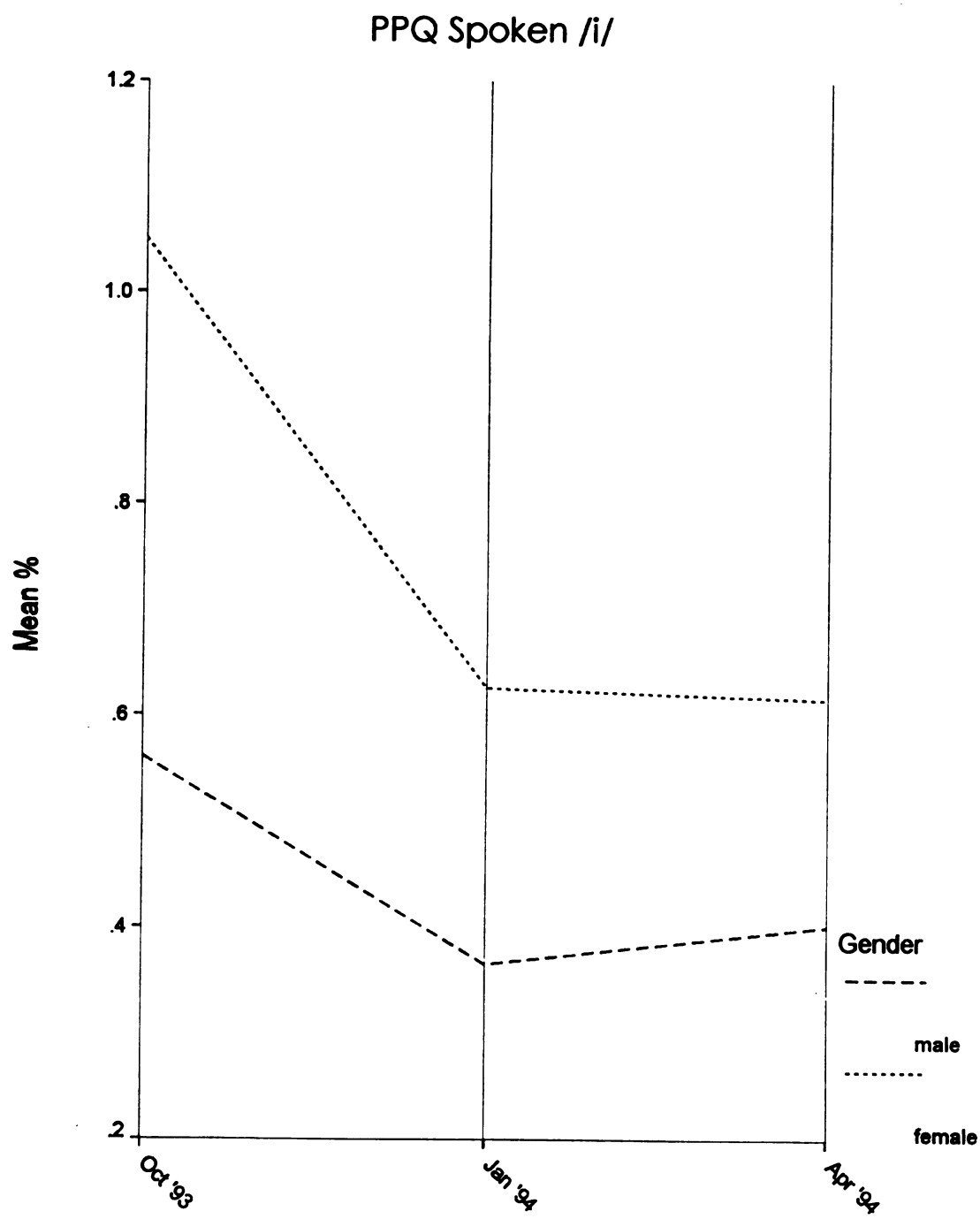

PPQ Spoken /i/
1.2
1.0
.8
.6
.4
.2
Mean %
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 43

APPENDIX P.6

sPPQ SPOKEN /i/

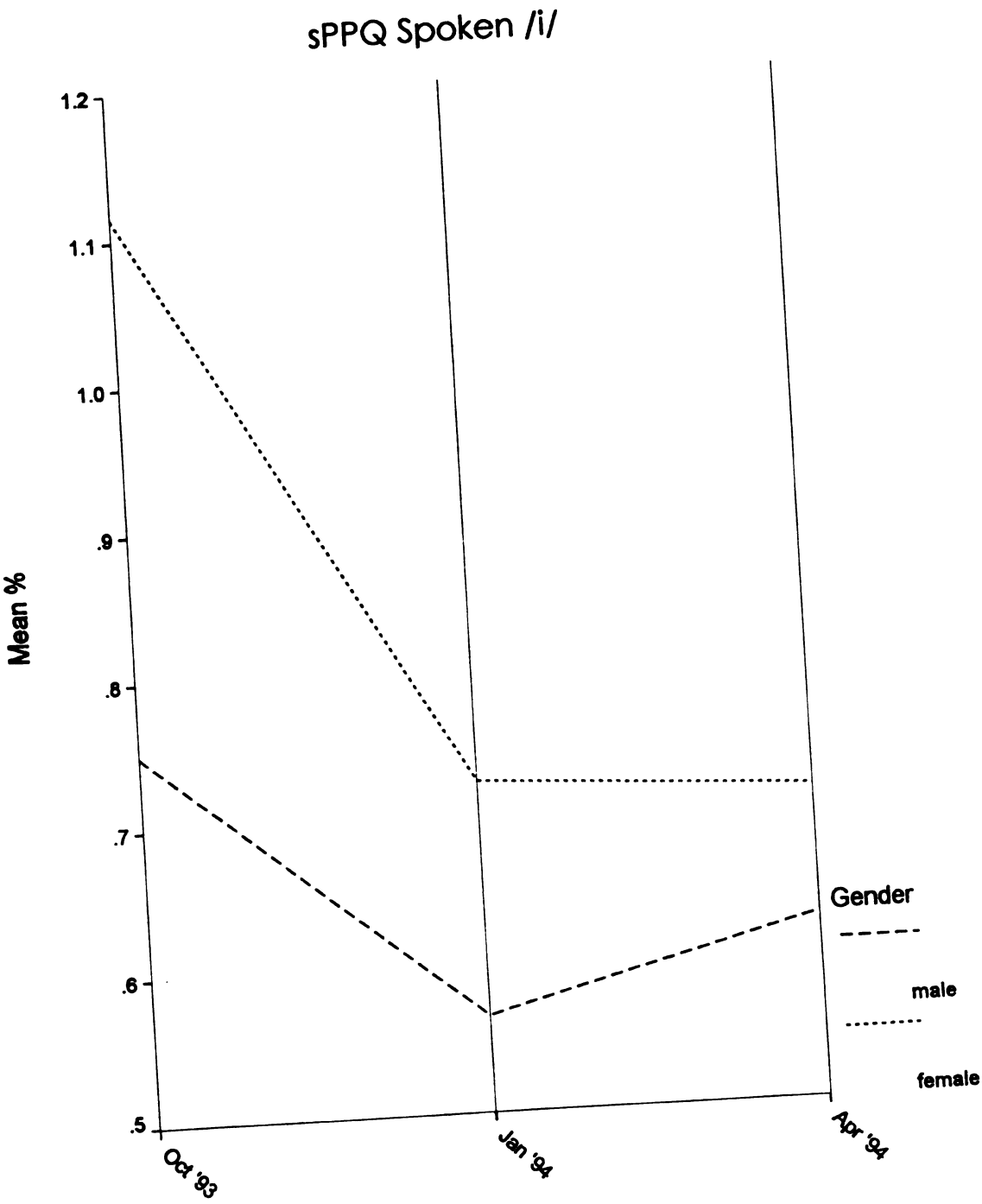

sPPQ Spoken /i/
Mean %
1.2
1.1
1.0
.9
.8
.7
.6
.5
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 44

APPENDIX P.7

vFo SPOKEN /i/

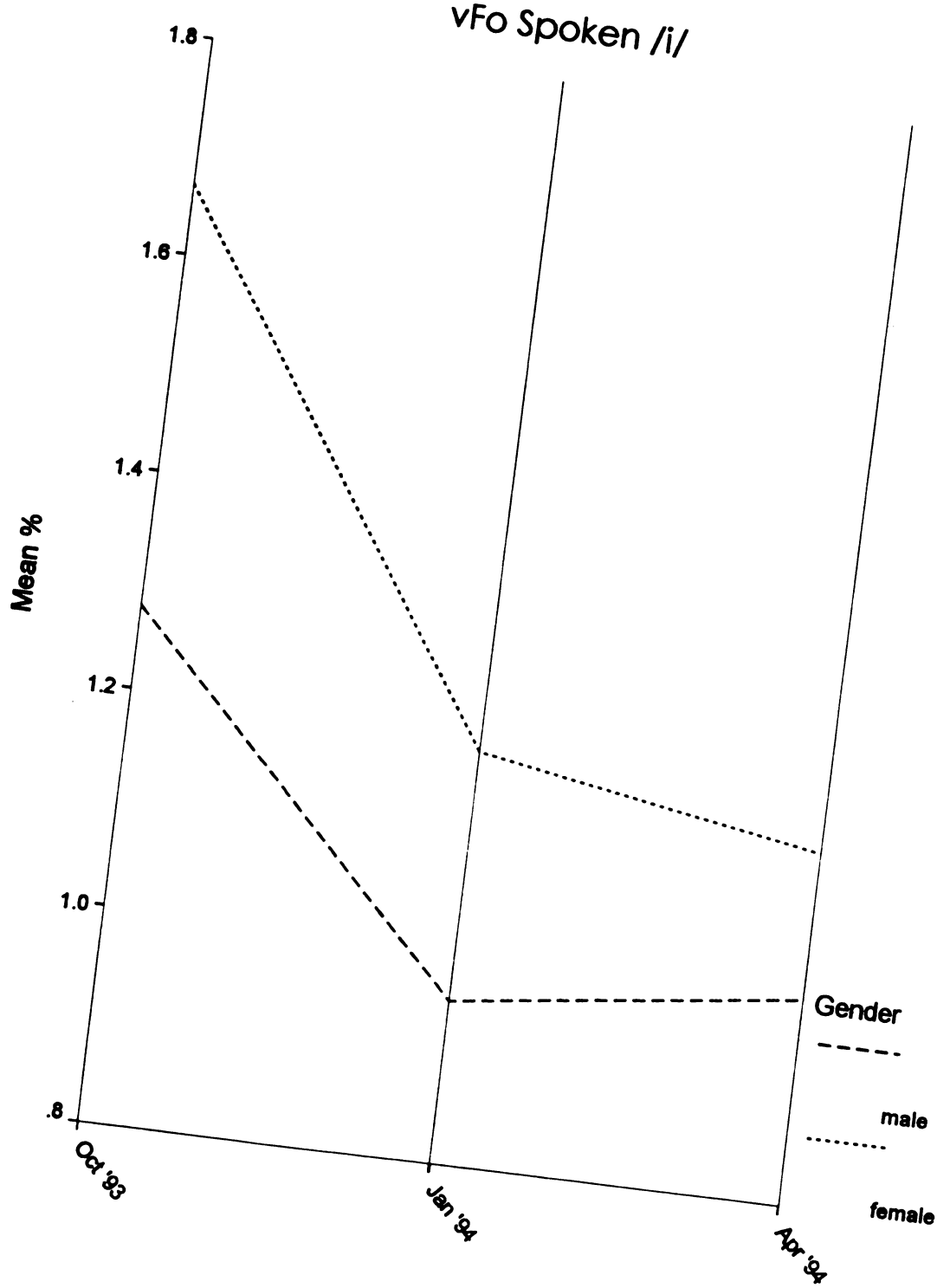

vFo Spoken /i/
1.8
1.6
1.4
1.2
1.0
.8
Mean %
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 45

APPENDIX Q.1

ShdB SPOKEN /i/

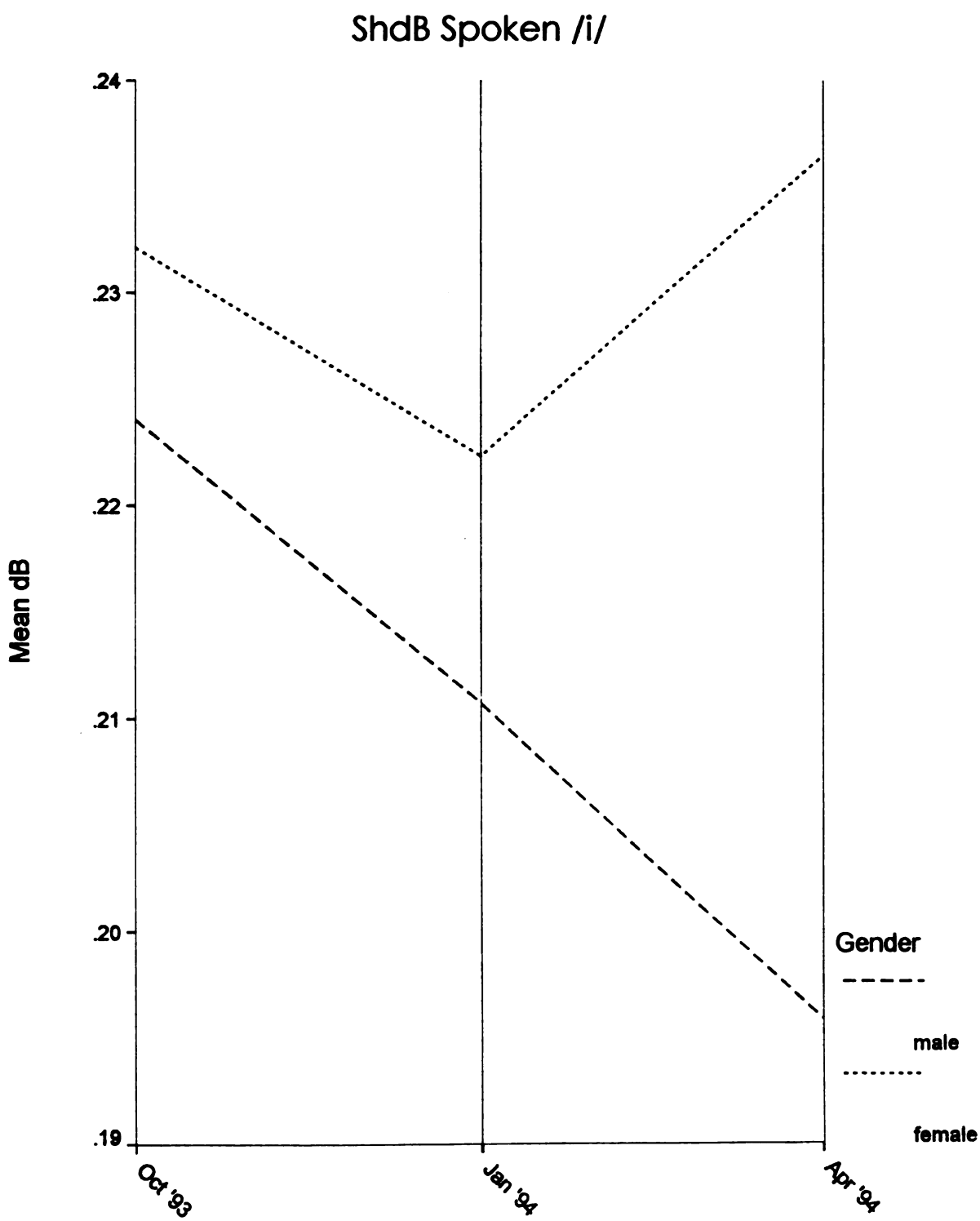

ShdB Spoken /i/
.24
.23
.22
.21
.20
.19
Mean dB
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 46

APPENDIX Q.2

Shim SPOKEN /i/

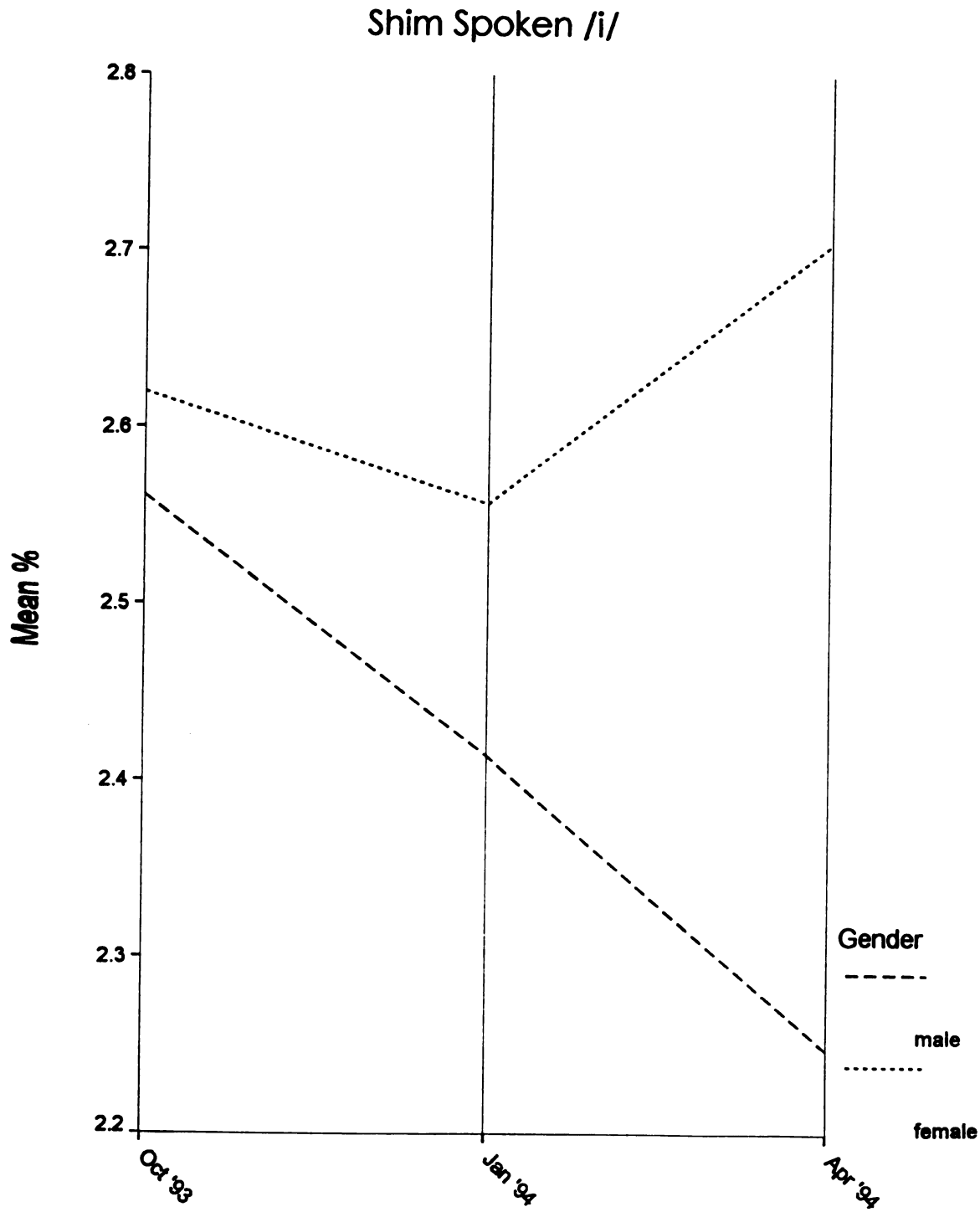

Shim Spoken /i/
Mean %
2.8
2.7
2.6
2.5
2.4
2.3
2.2
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 47

APPENDIX Q.3

APQ SPOKEN /i/

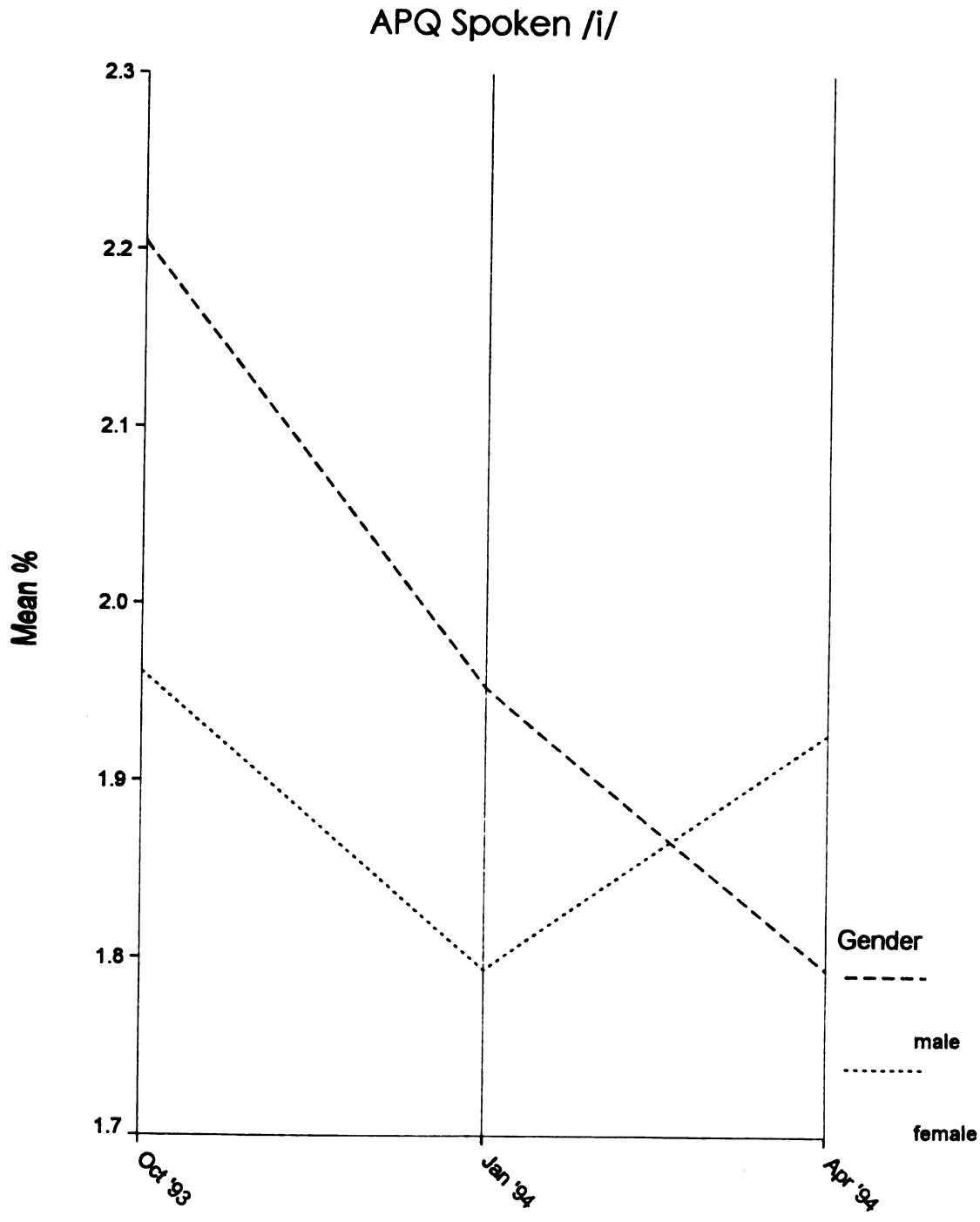

APQ Spoken /i/
Mean %
2.3
2.2
2.1
2.0
1.9
1.8
1.7
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 48

APPENDIX Q.4

sAPQ SPOKEN /i/

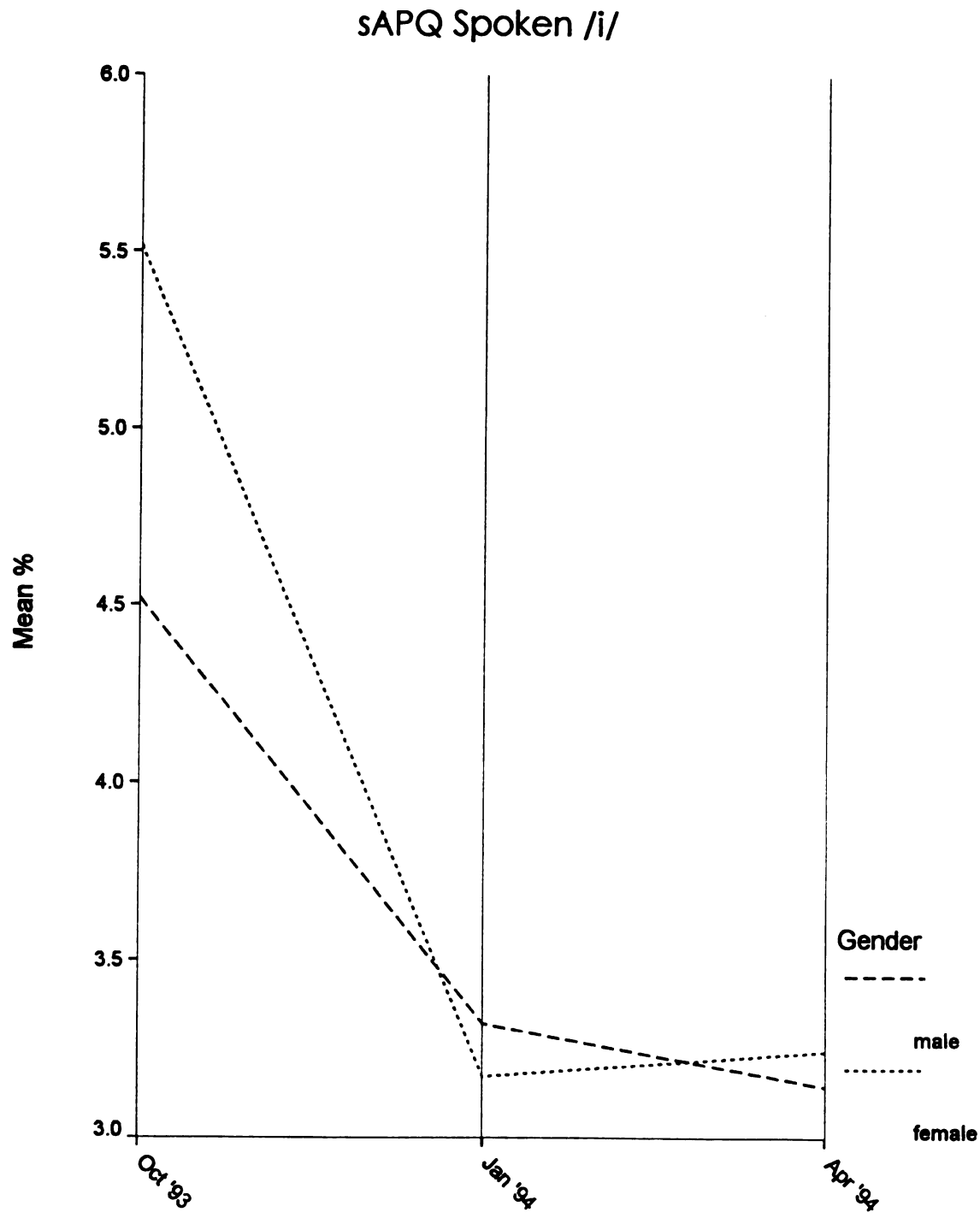

sAPQ Spoken /i/
6.0
5.5
5.0
4.5
4.0
3.5
3.0
Mean %
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 49

APPENDIX Q.5

vAm SPOKEN /i/

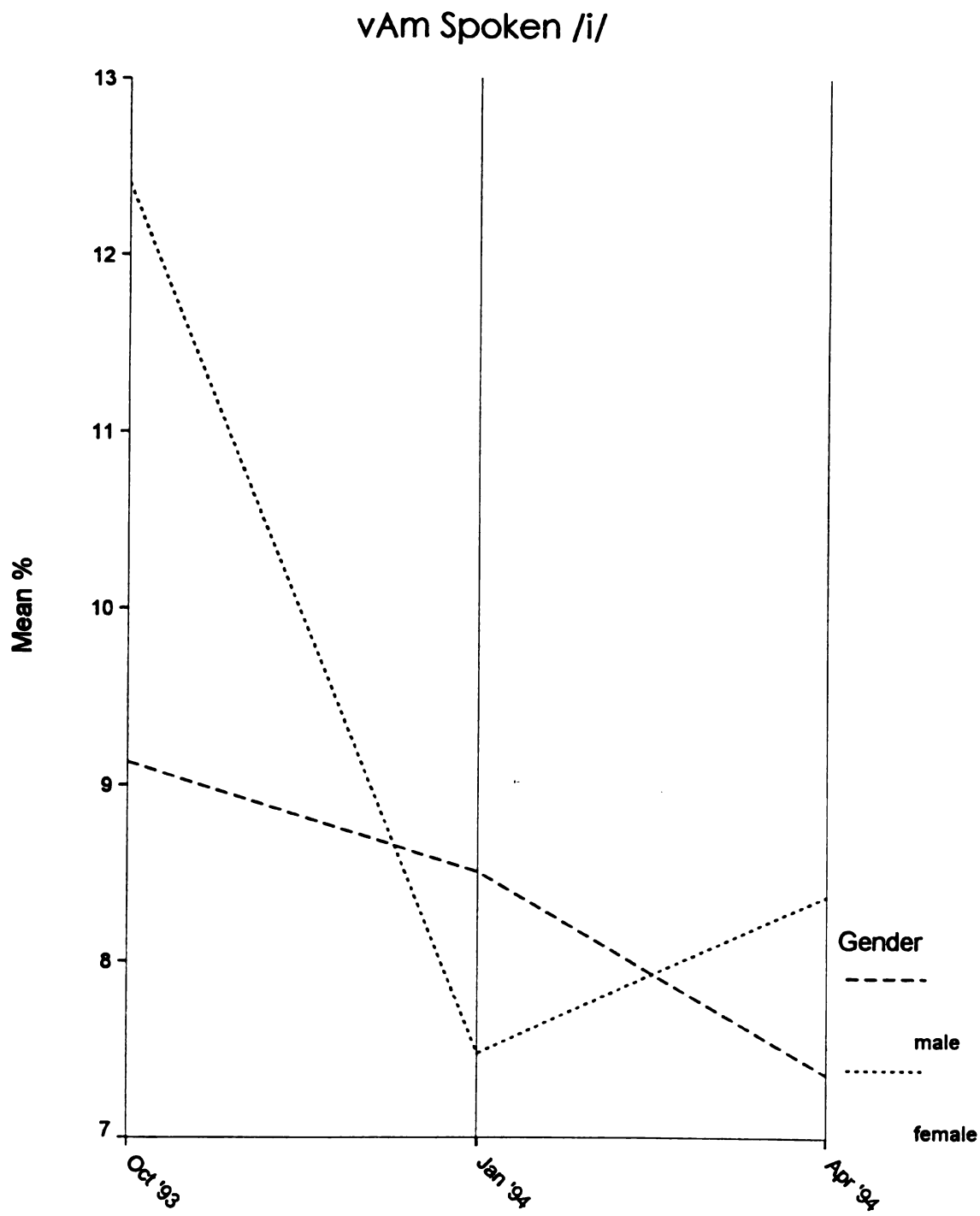

vAm Spoken /i/
Mean %
13
12
11
10
9
8
7
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 50

APPENDIX R.1

NHR SPOKEN /i/

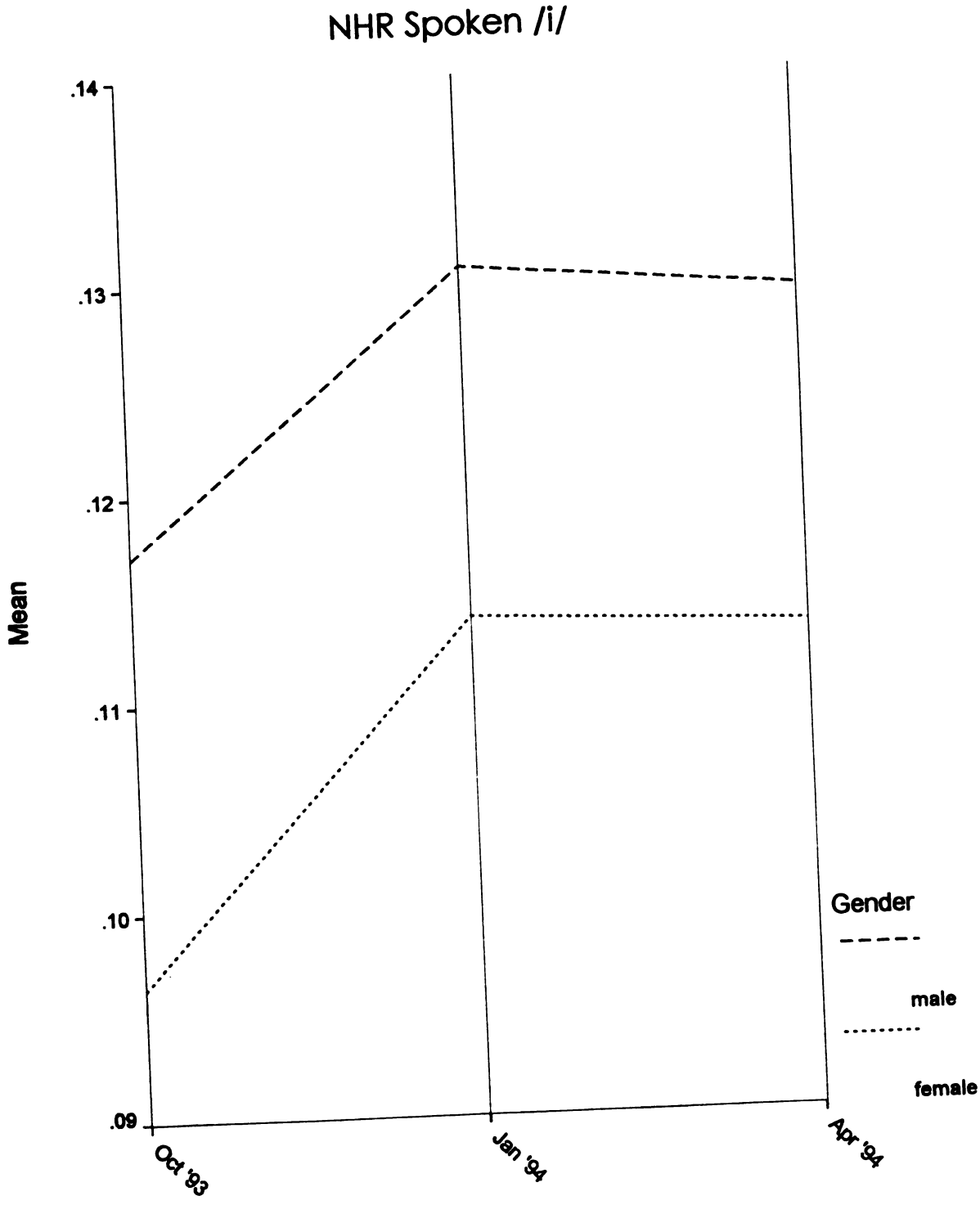

NHR Spoken /i/
.14
.13
.12
.11
.10
.09
Mean
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 51

APPENDIX R.2

VTI SPOKEN /i/

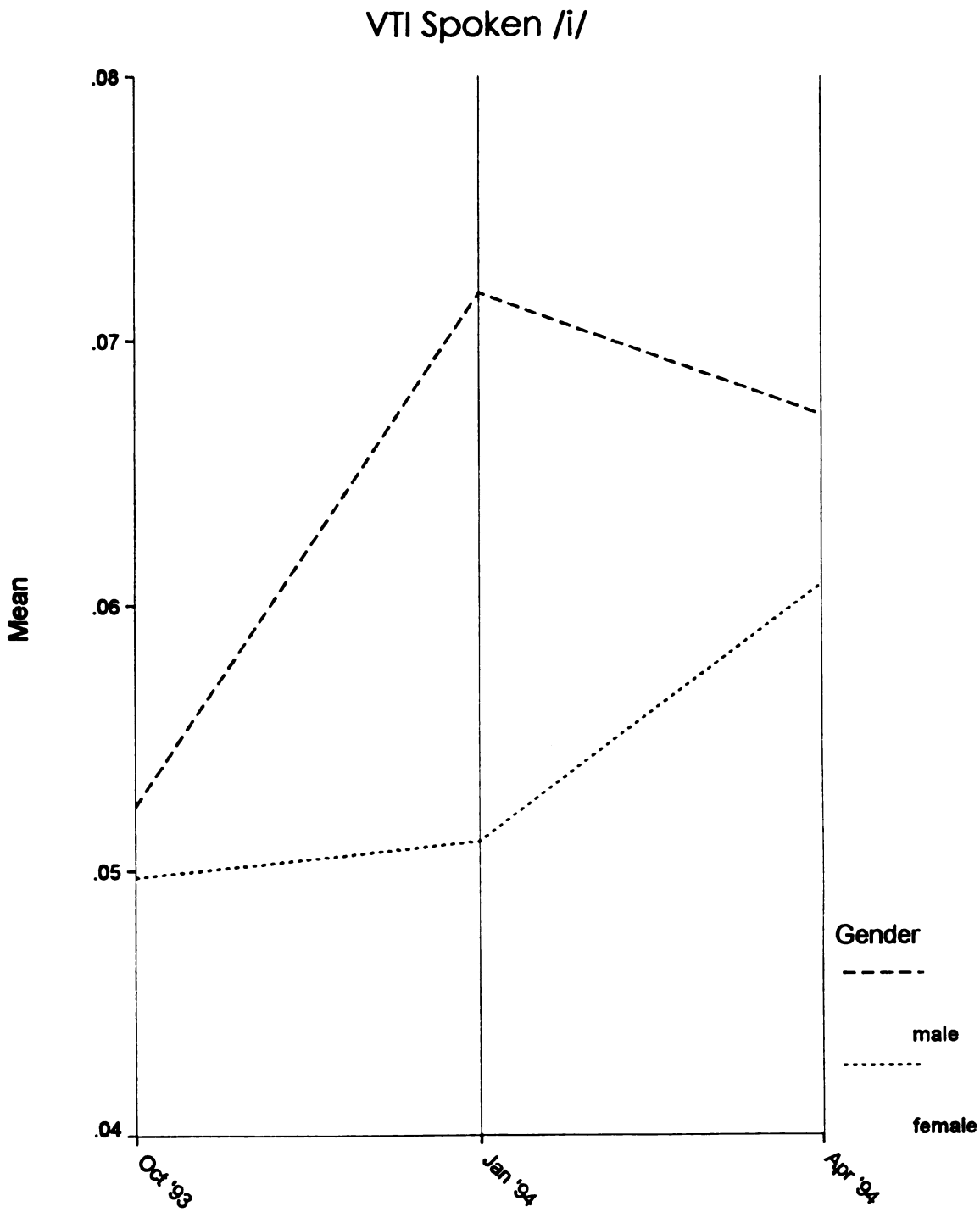

VTI Spoken /i/
.08
.07
.06
.05
.04
Mean
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 52

APPENDIX R.3

SPI SPOKEN /i/

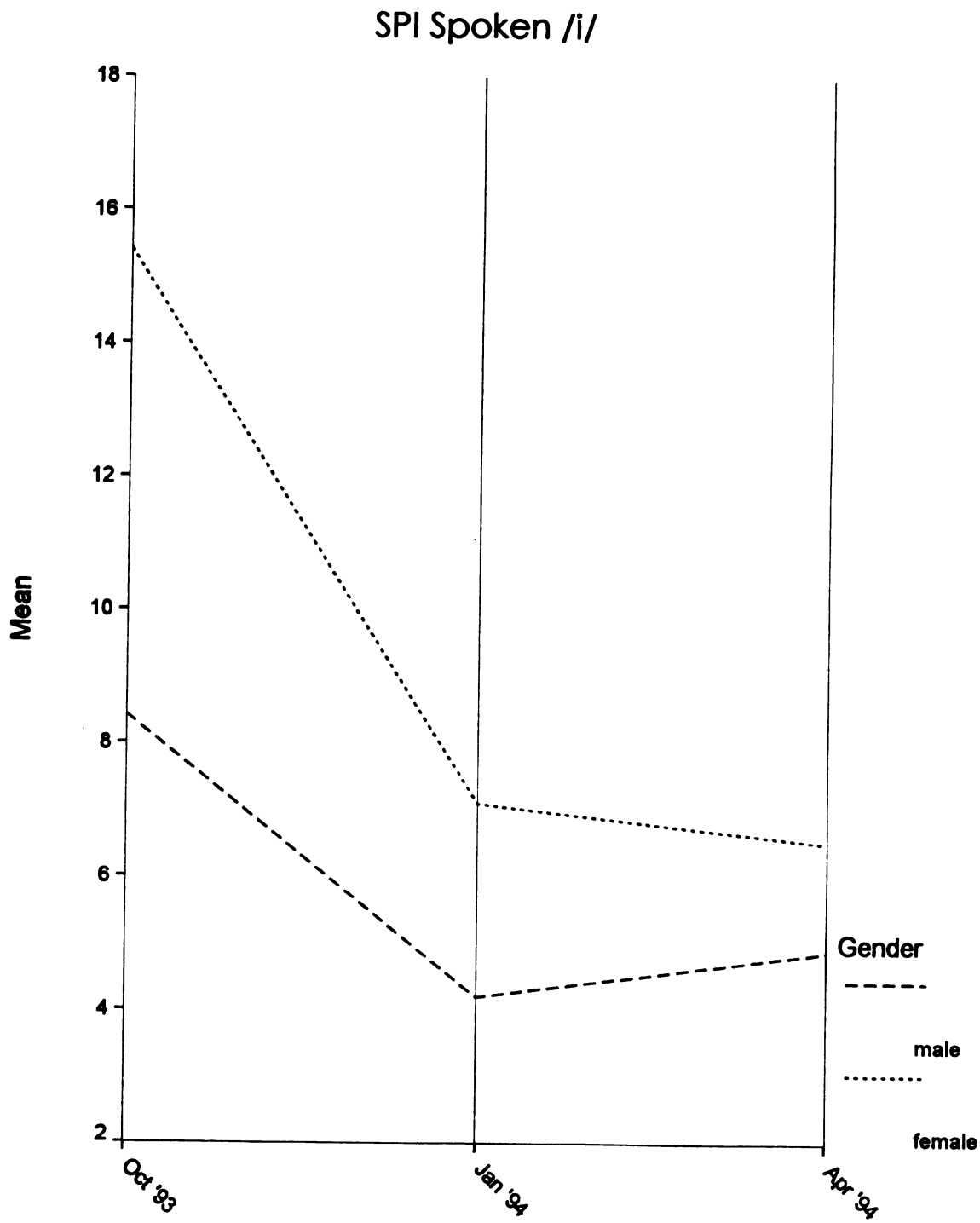

SPI Spoken /i/
Mean
18
16
14
12
10
8
6
4
2
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 53

APPENDIX S.1

FTRI SPOKEN /i/

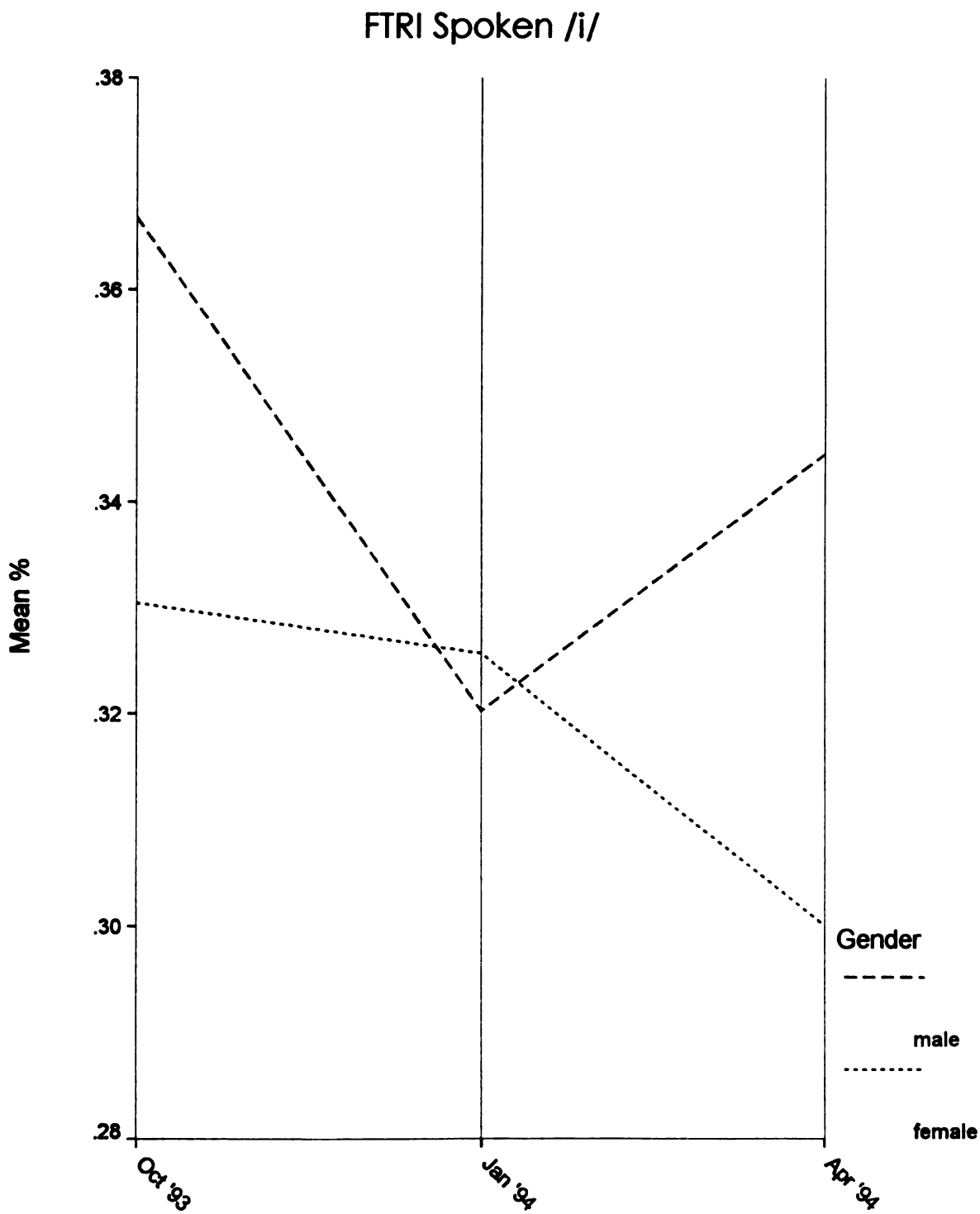

FTRI Spoken /i/
.38
.36
.34
.32
.30
.28
Mean %
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 54

APPENDIX S.2

ATRI SPOKEN /i/

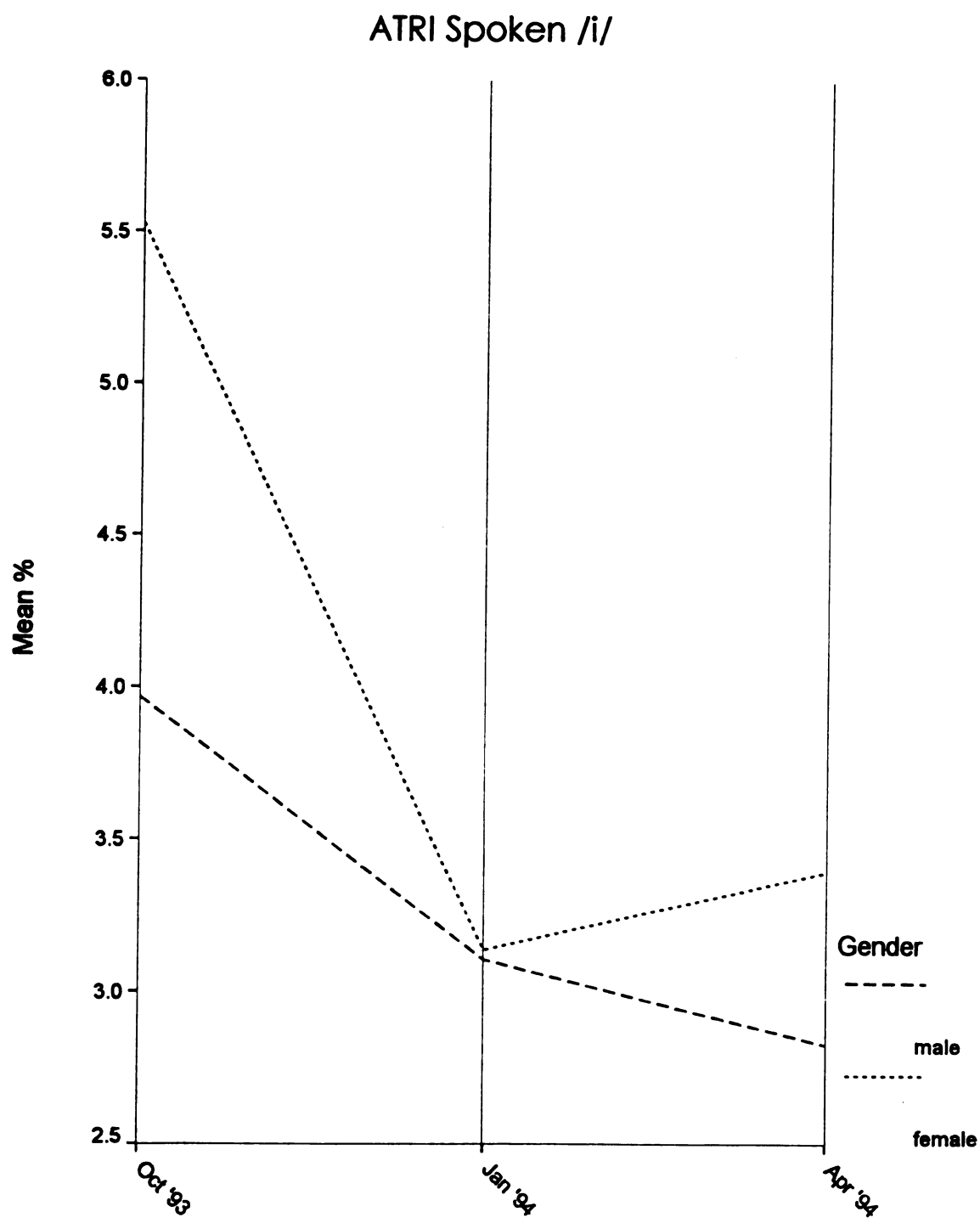

ATRI Spoken /i/
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
Mean %
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 55

APPENDIX S.3

Fftr SPOKEN /i/

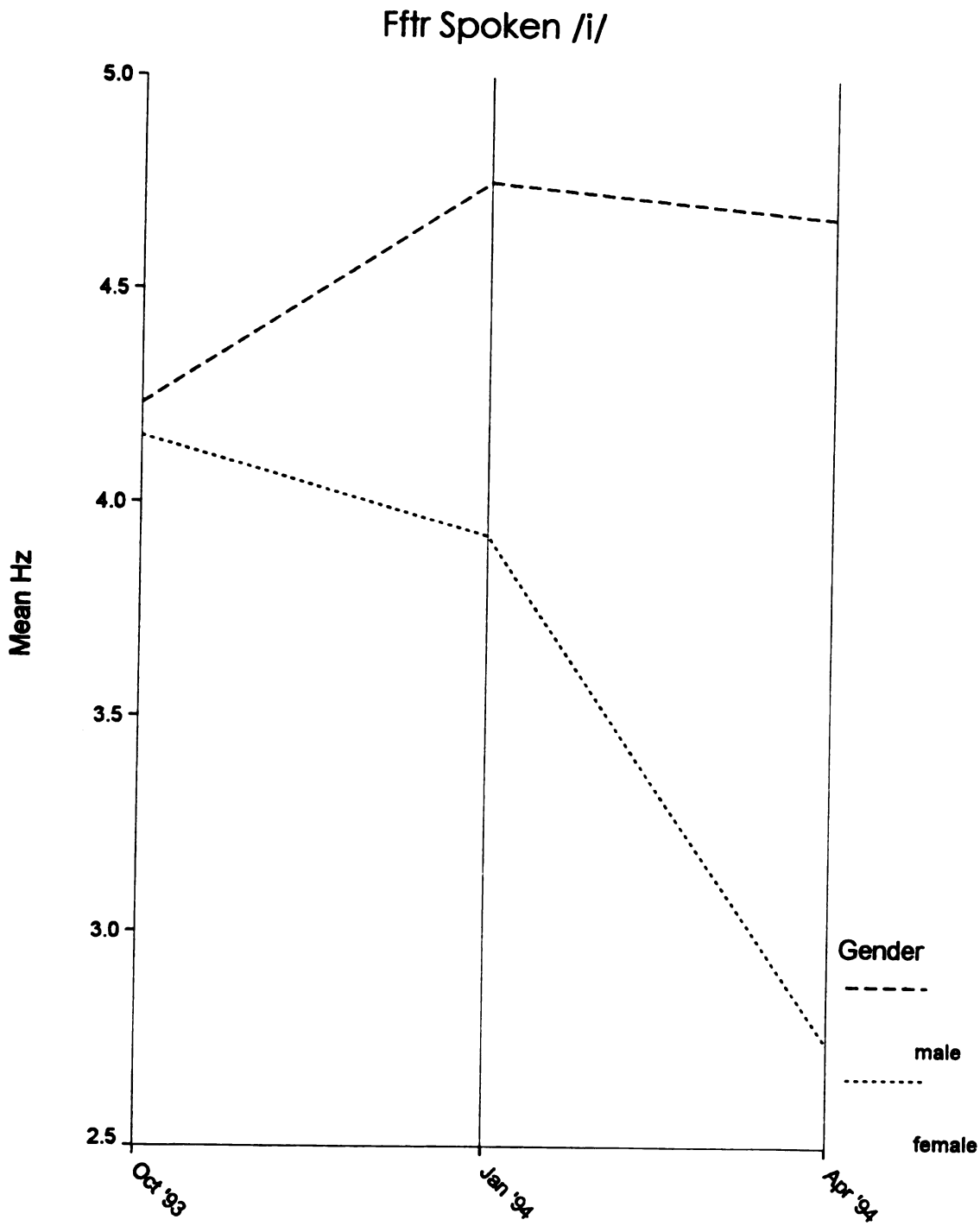

Fftr Spoken /i/
5.0
4.5
4.0
3.5
3.0
2.5
Mean Hz
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 56

APPENDIX S.4

Fatr SPOKEN /i/

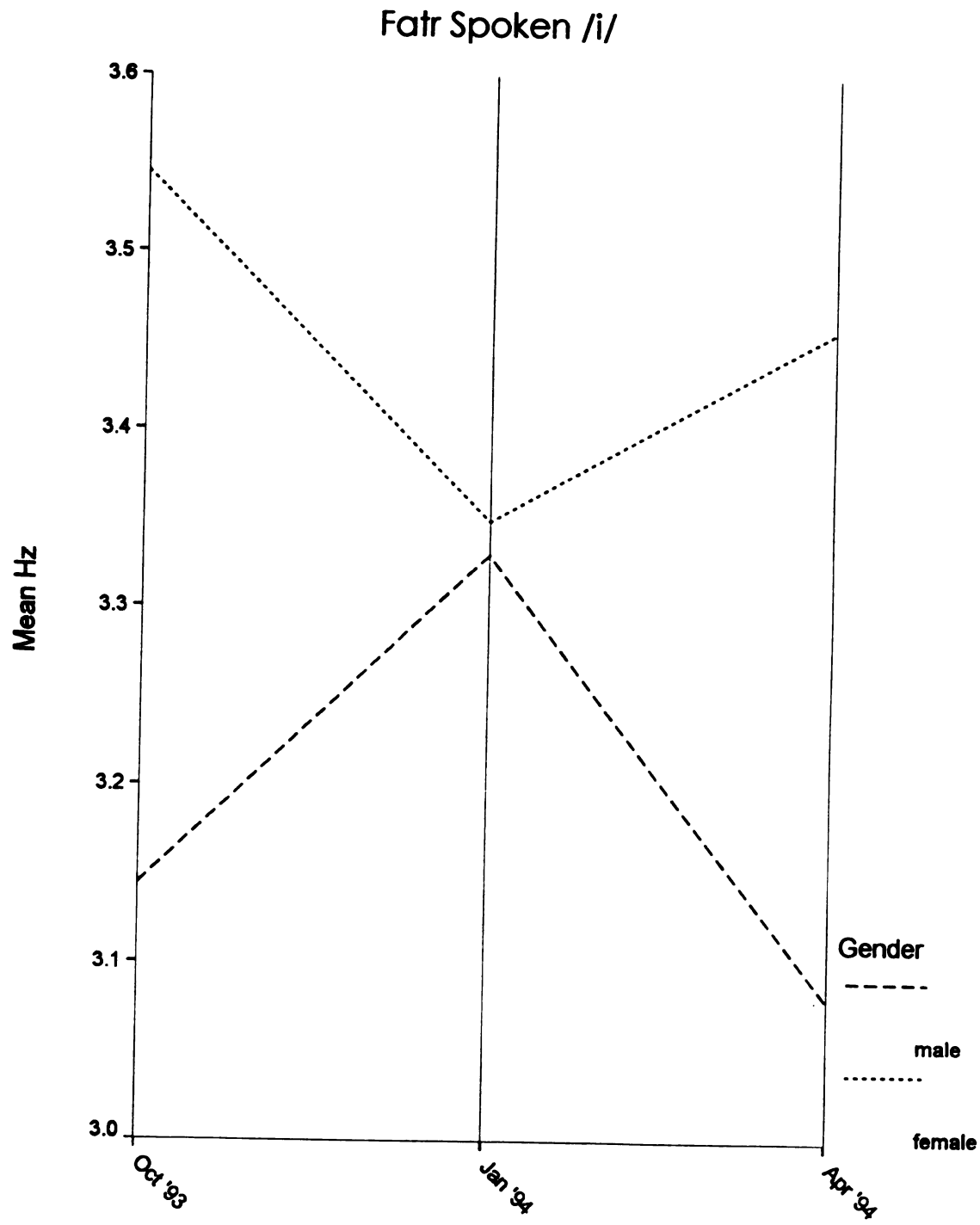

Fatr Spoken /i/
3.6
3.5
3.4
3.3
3.2
3.1
3.0
Mean Hz
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 57

APPENDIX T.1

Fo SUNG /i/

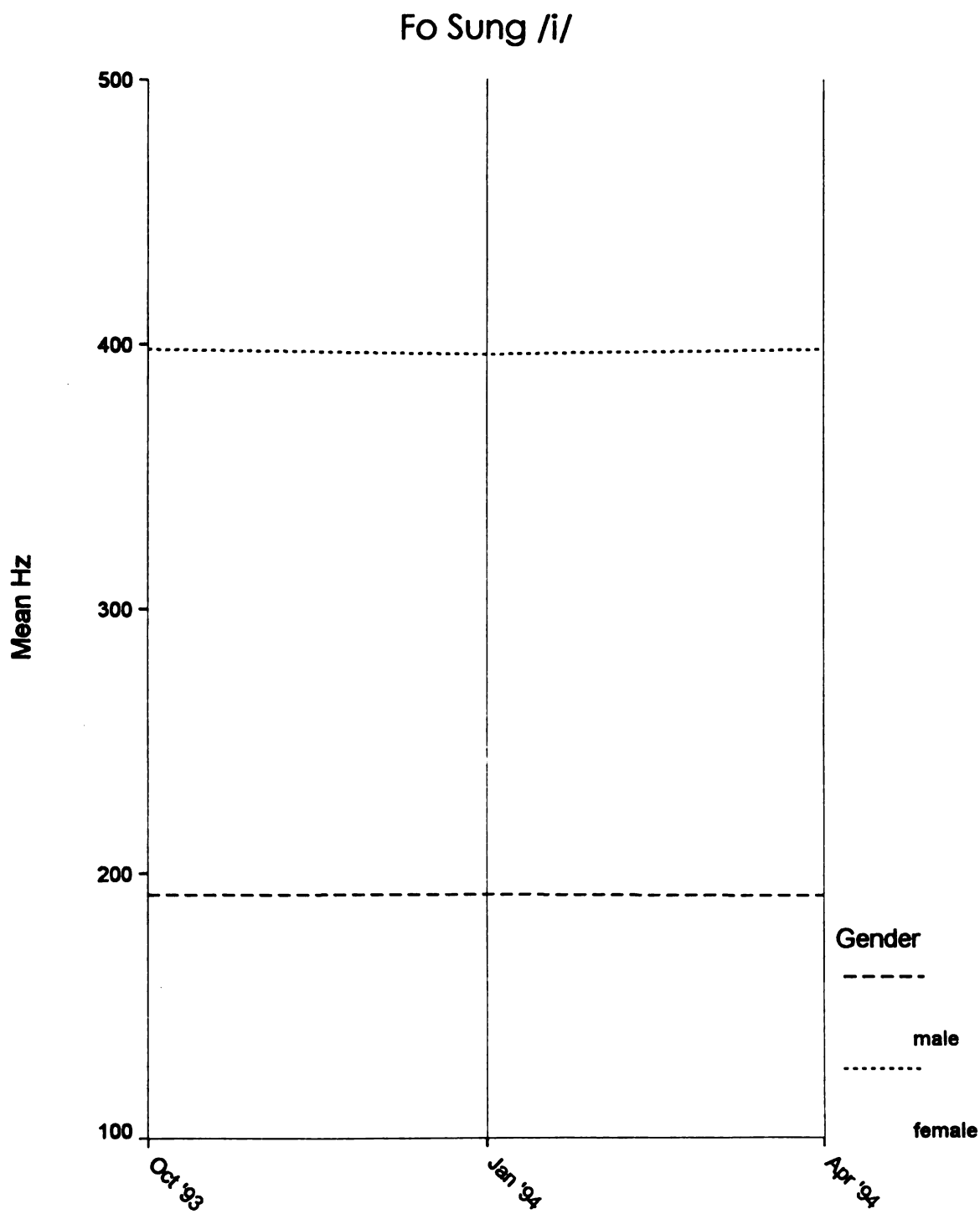

Fo Sung /i/
500
400
300
200
100
Mean Hz
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 58

APPENDIX T.2

Jita SUNG /i/

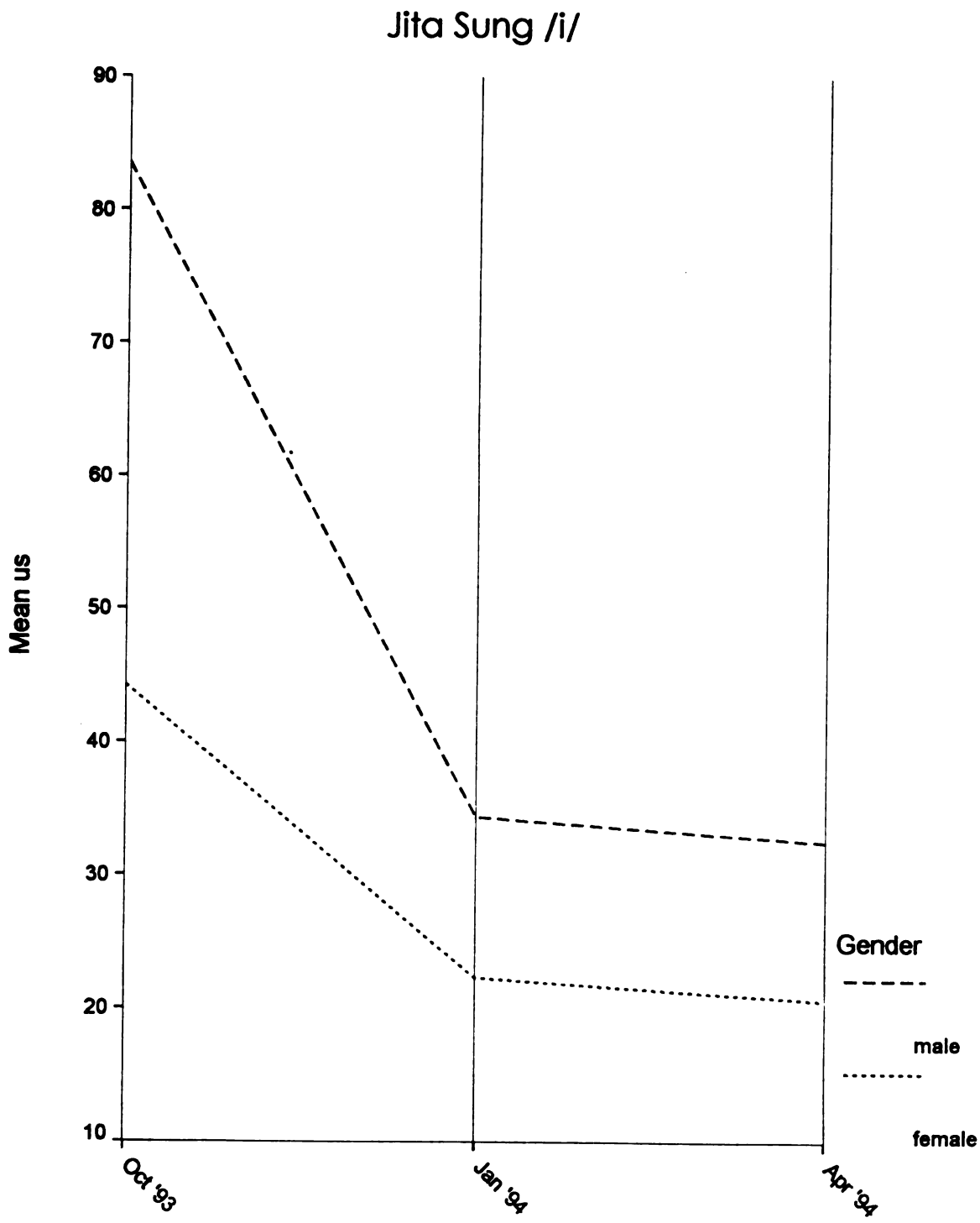

Jita Sung /i/
Mean us
90
80
70
60
50
40
30
20
10
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 59

APPENDIX T.3

Jitt SUNG /i/

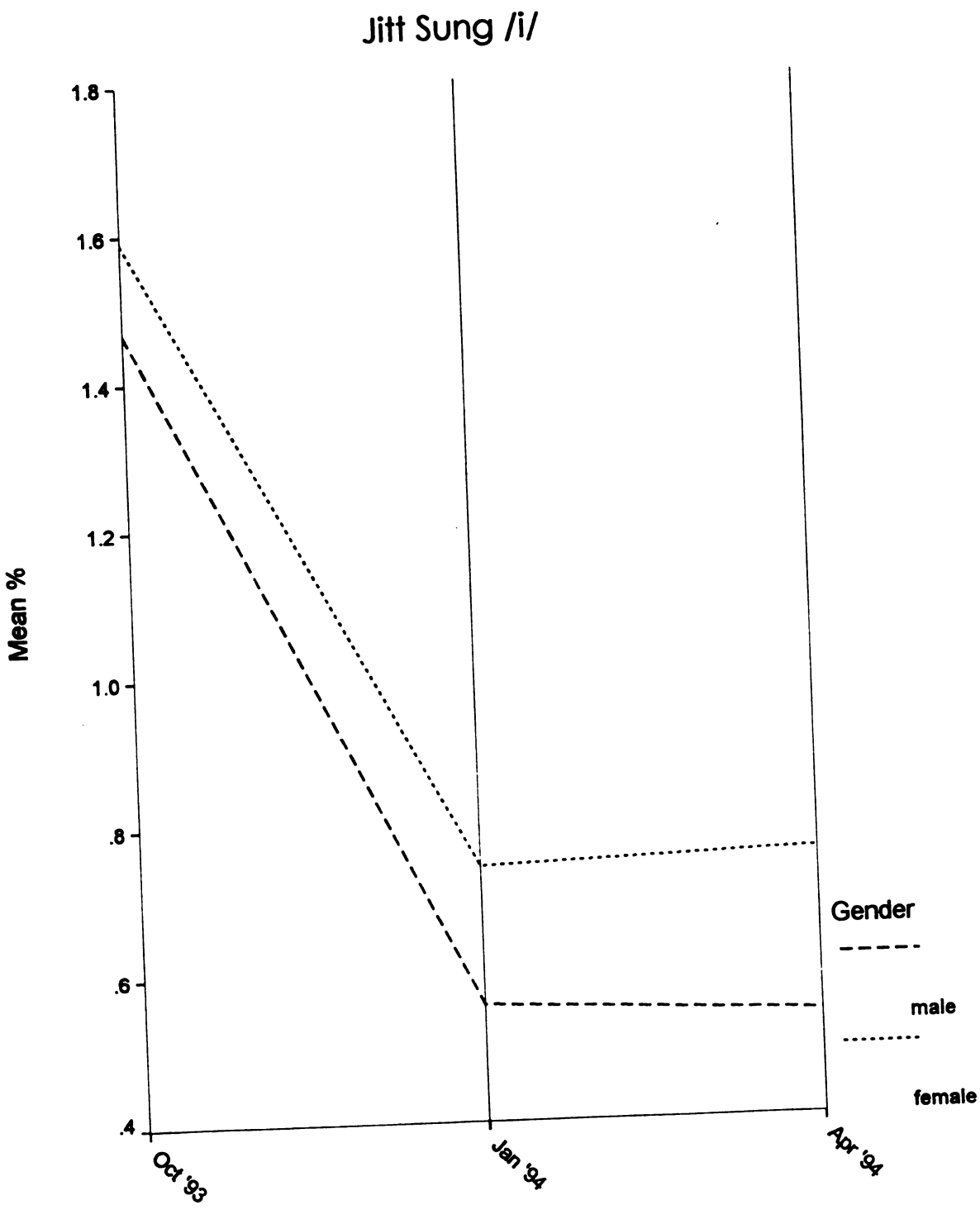

Jitt Sung /i/
Mean %
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 60

APPENDIX T.4

RAP SUNG /i/

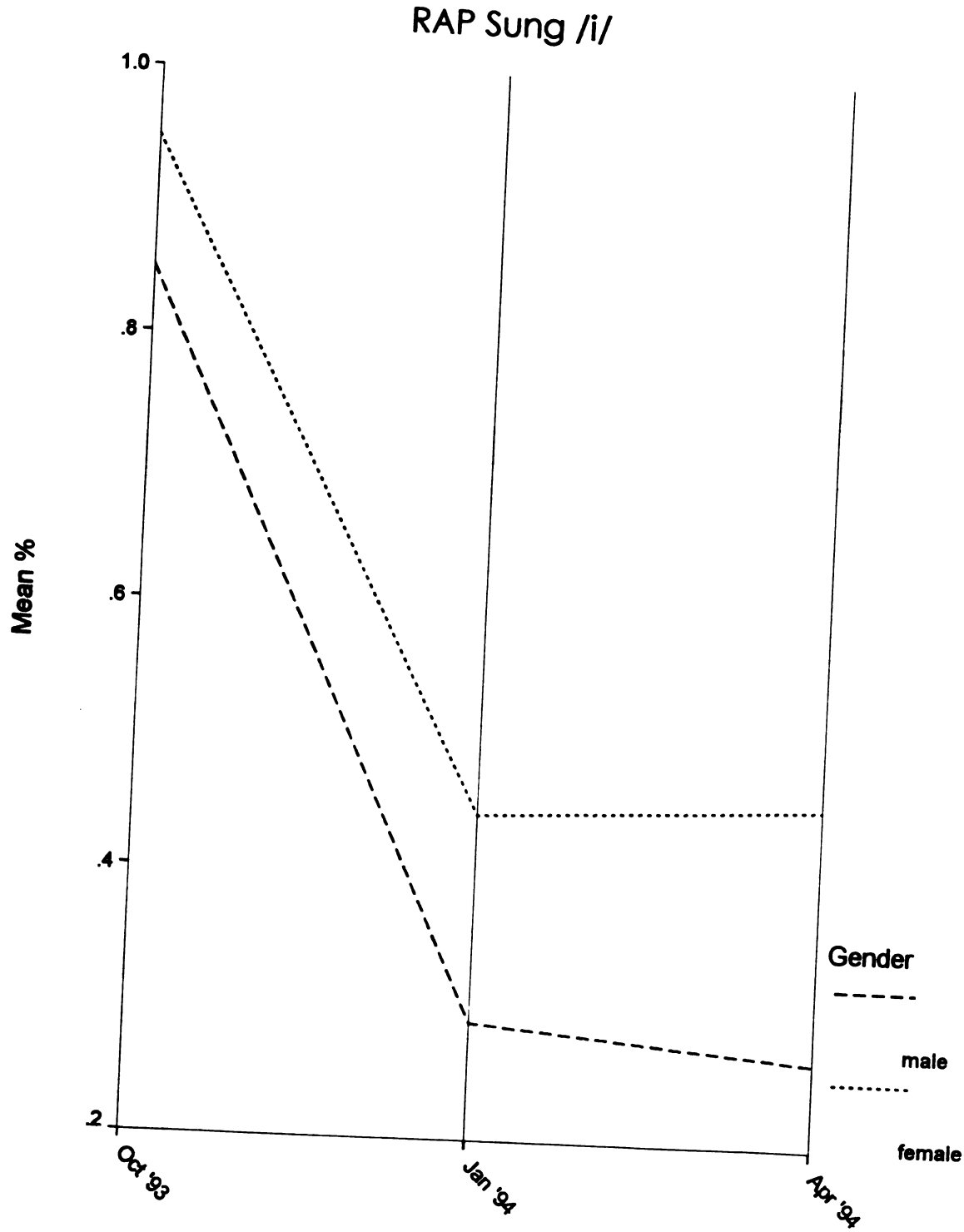


FIGURE 61

APPENDIX T.5

PPQ SUNG /i/

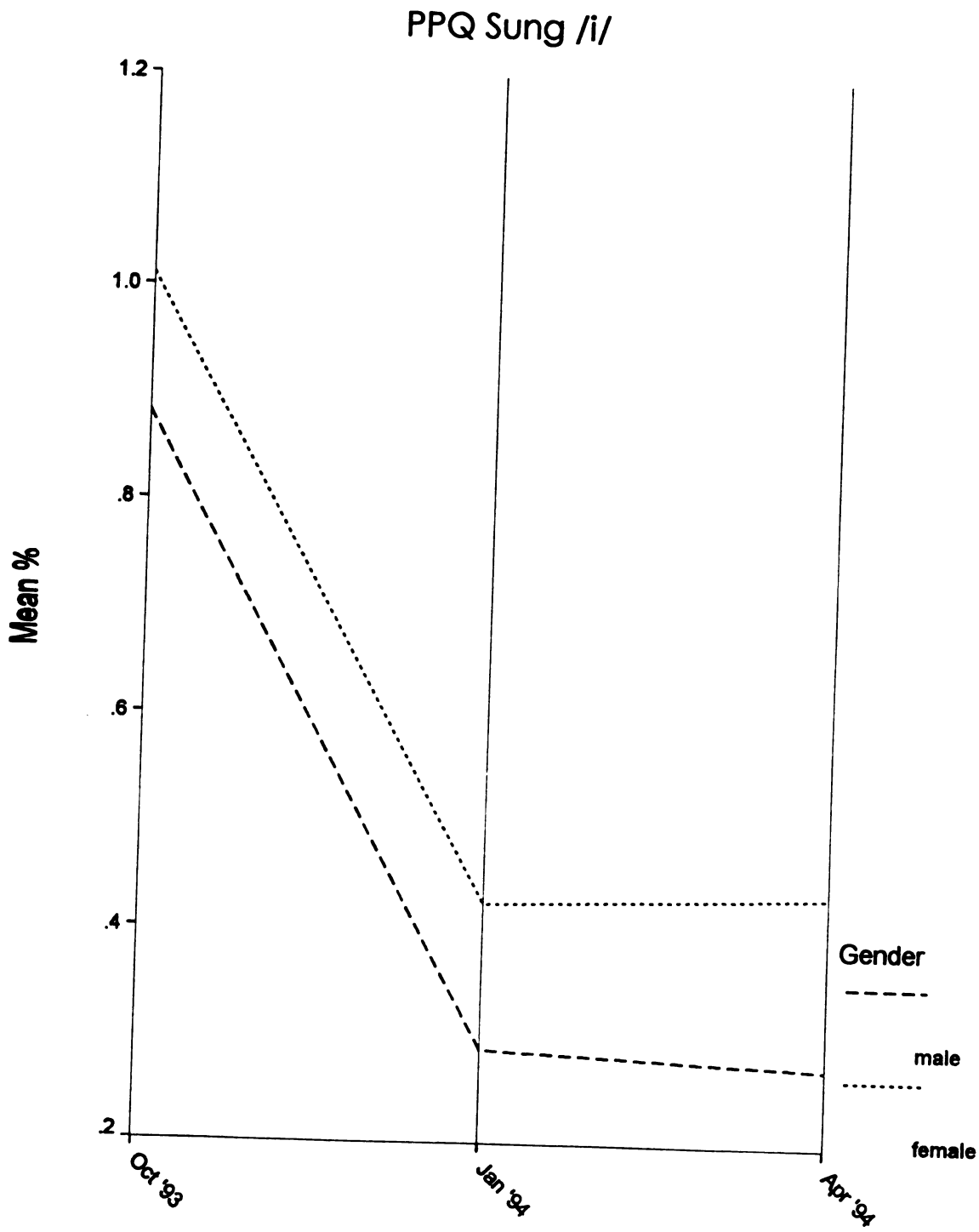

PPQ Sung /i/
1.2
1.0
.8
.6
.4
.2
Mean %
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 62

APPENDIX T.6

sPPQ SUNG /i/

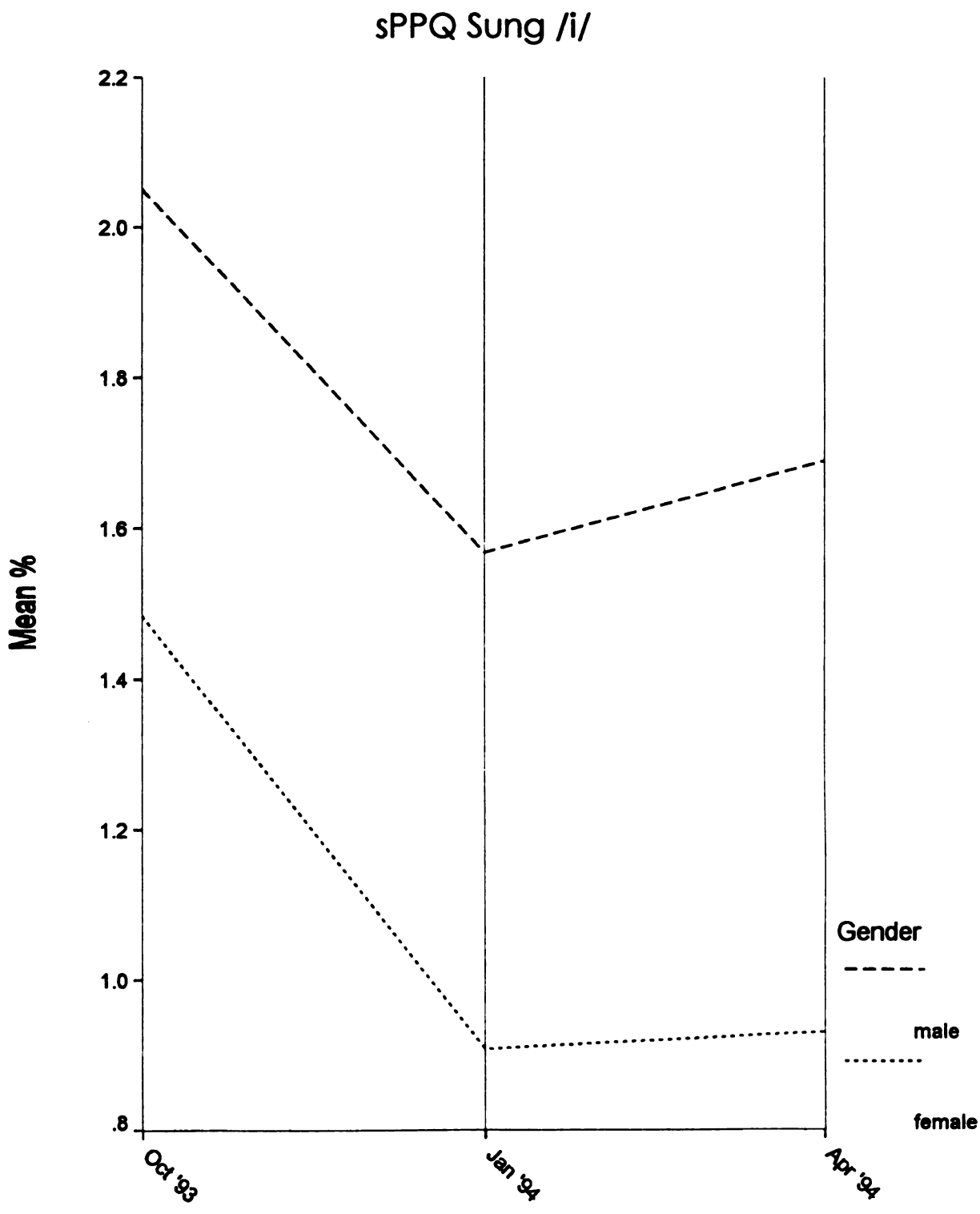

sPPQ Sung /i/
Mean %
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 63

APPENDIX T.7

vFo SUNG /i/

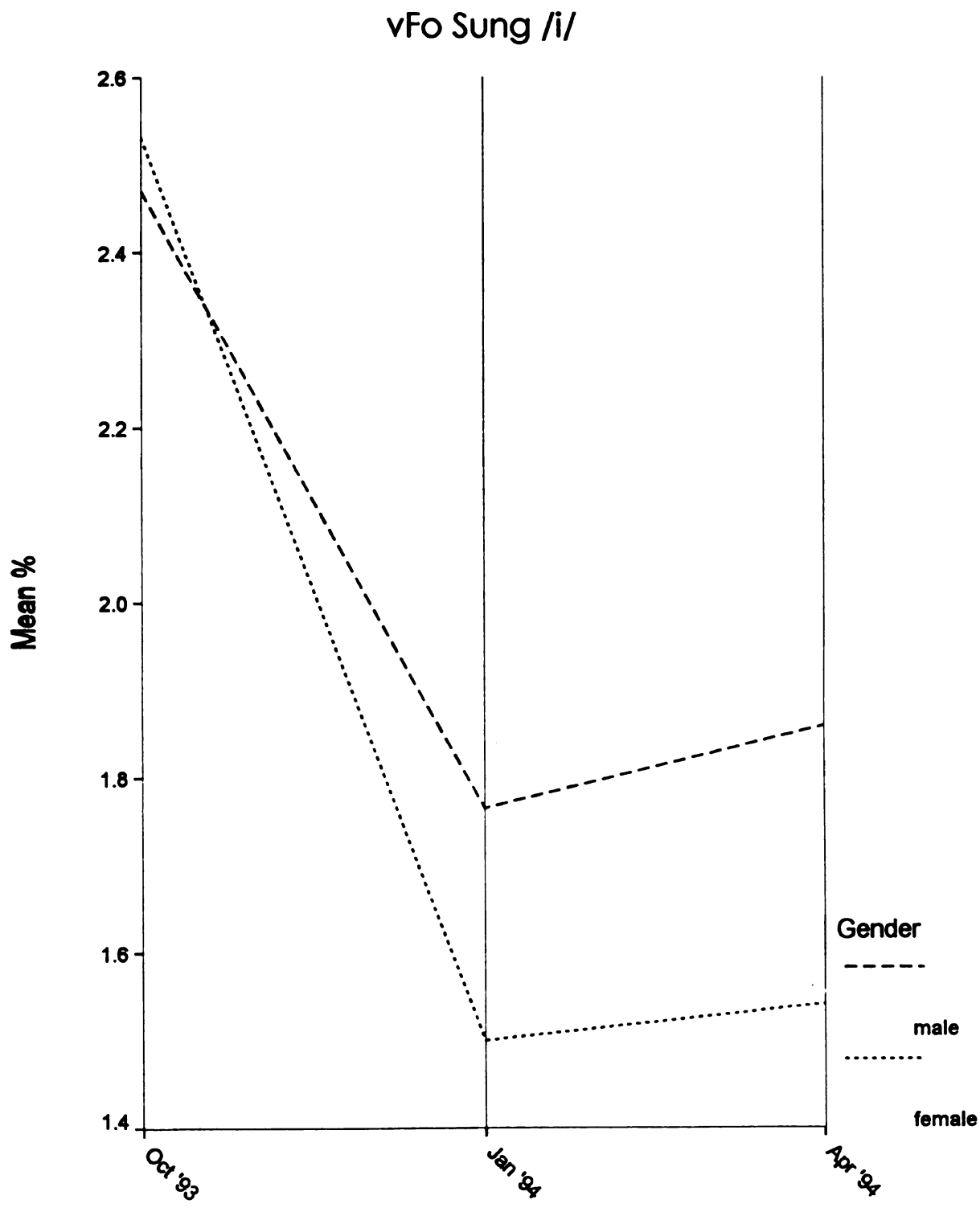

vFo Sung /i/
Mean %
2.6
2.4
2.2
2.0
1.8
1.6
1.4
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 64

APPENDIX U.1

ShdB SUNG /i/

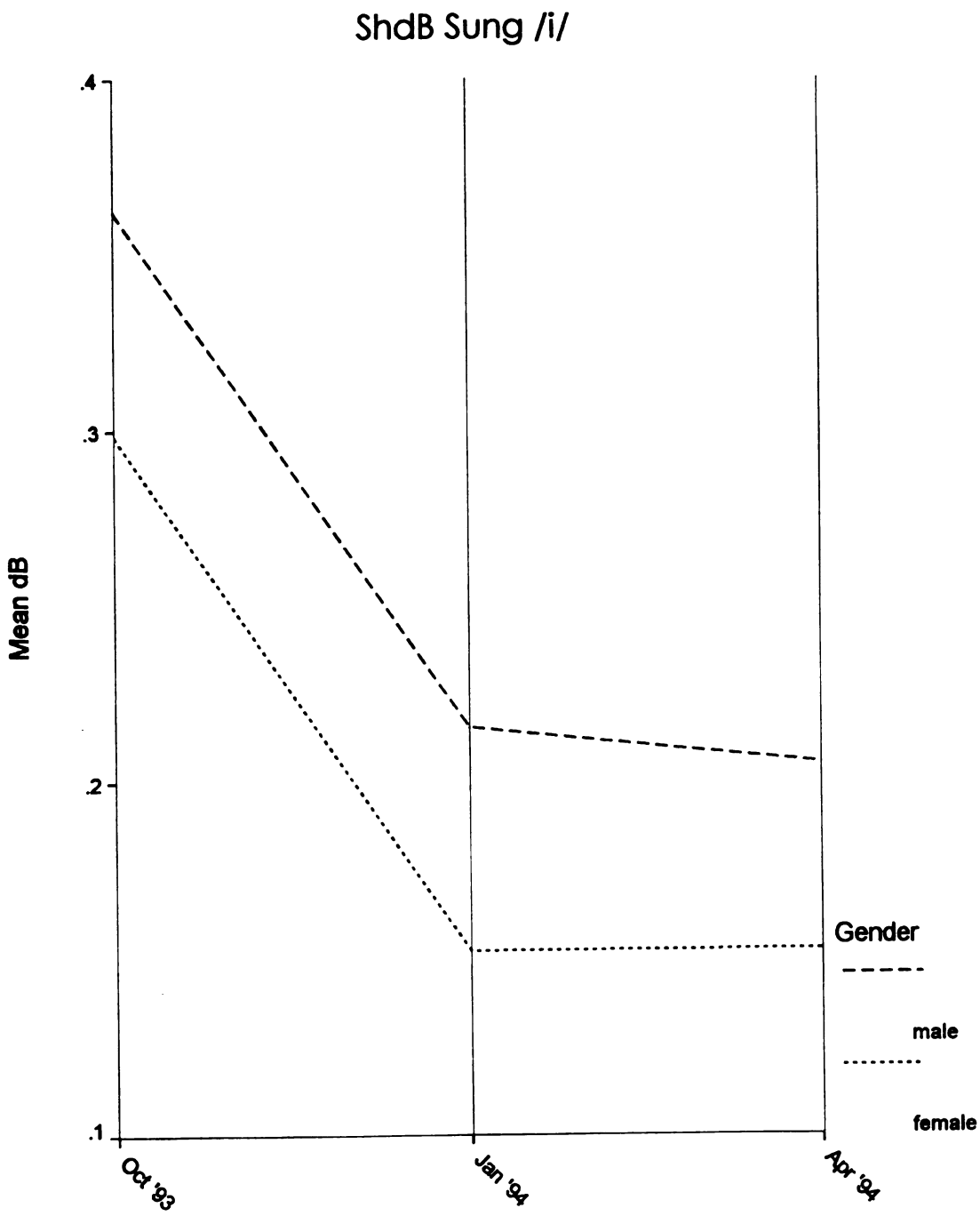

ShdB Sung /i/
.4
.3
.2
.1
Mean dB
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 65

APPENDIX U.2

Shim SUNG /i/

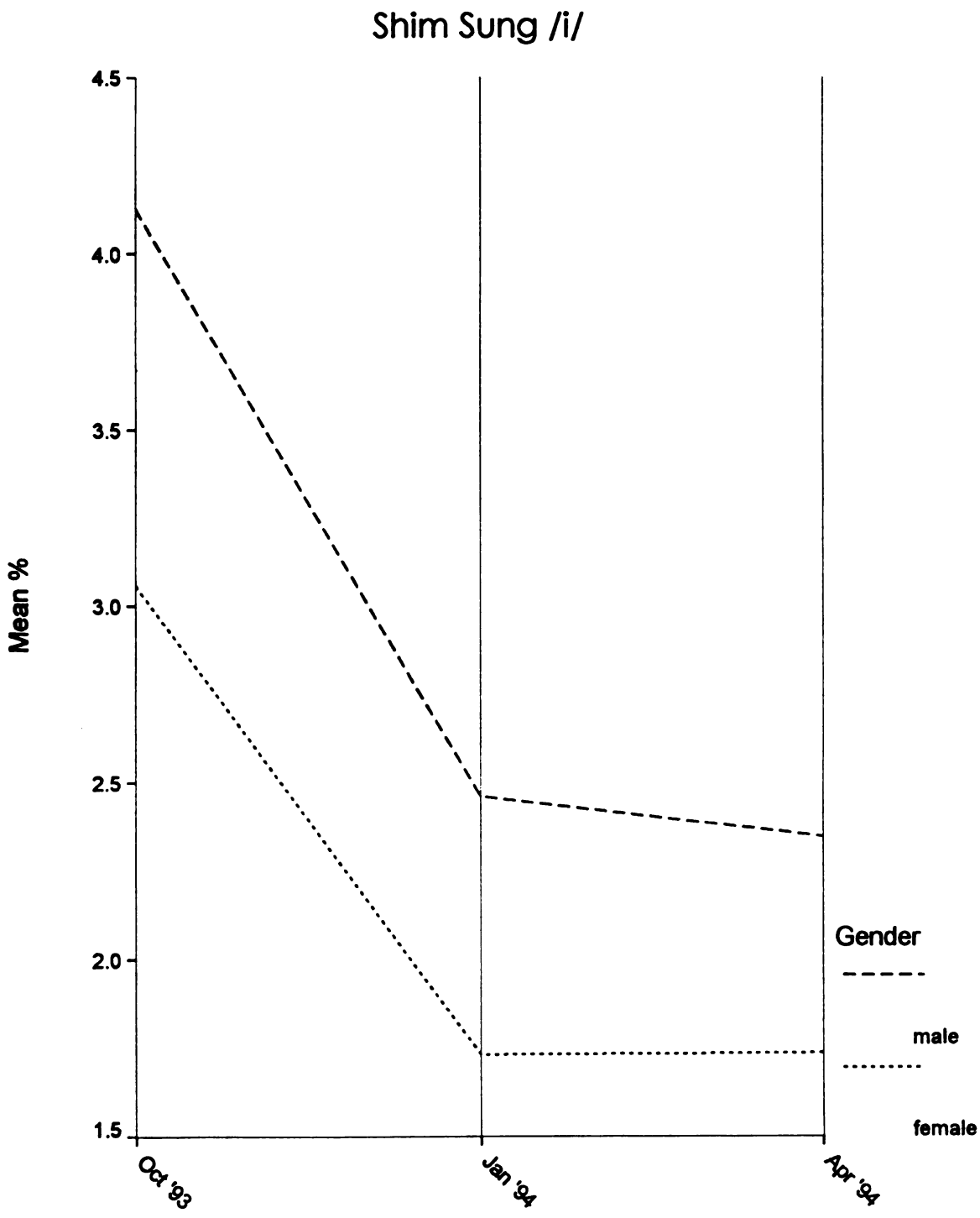

Shim Sung /i/
4.5
4.0
3.5
3.0
2.5
2.0
1.5
Mean %
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 66

APPENDIX U.3

APQ SUNG /i/

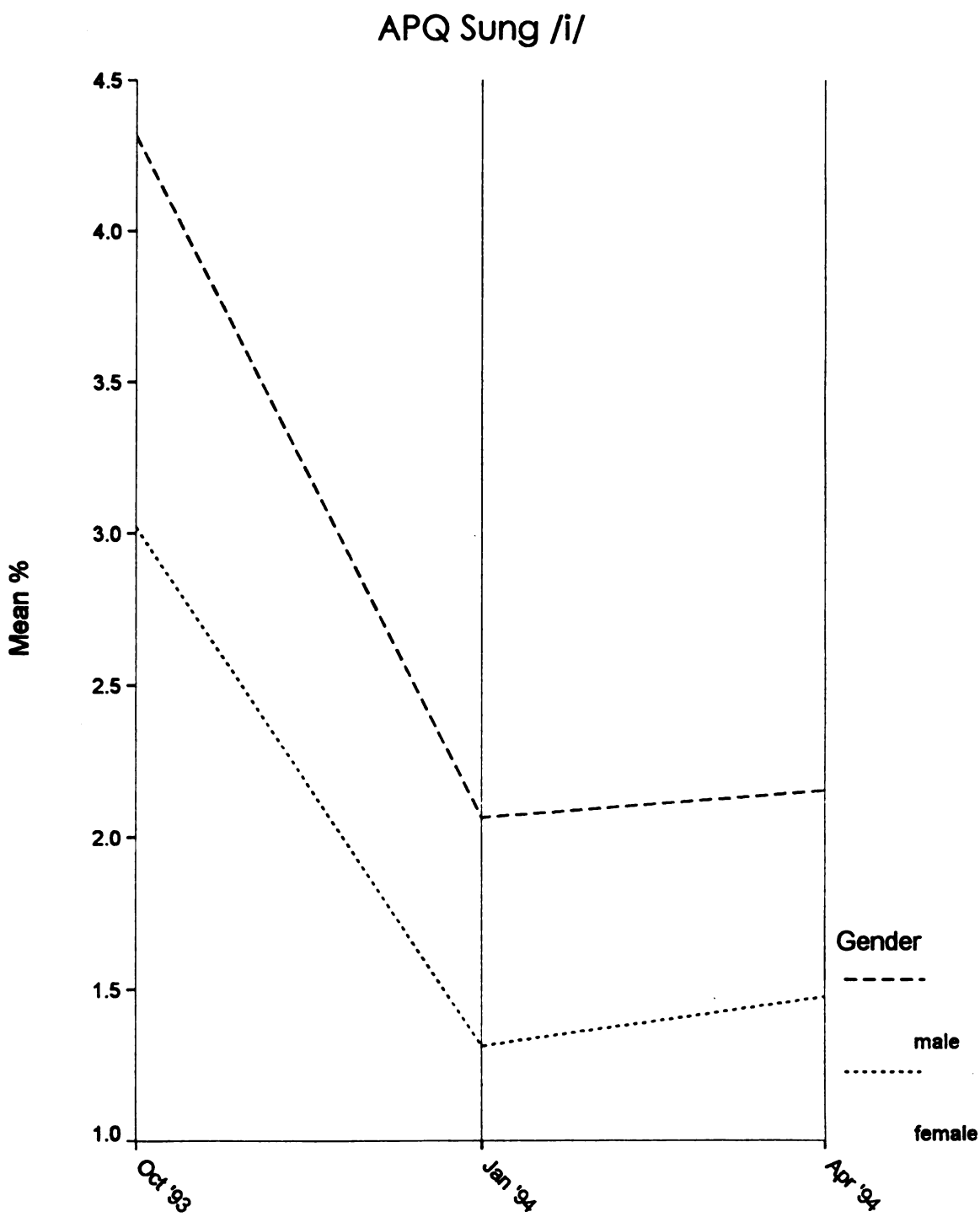

APQ Sung /i/
Mean %
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 67

APPENDIX U.4

sAPQ SUNG /i/

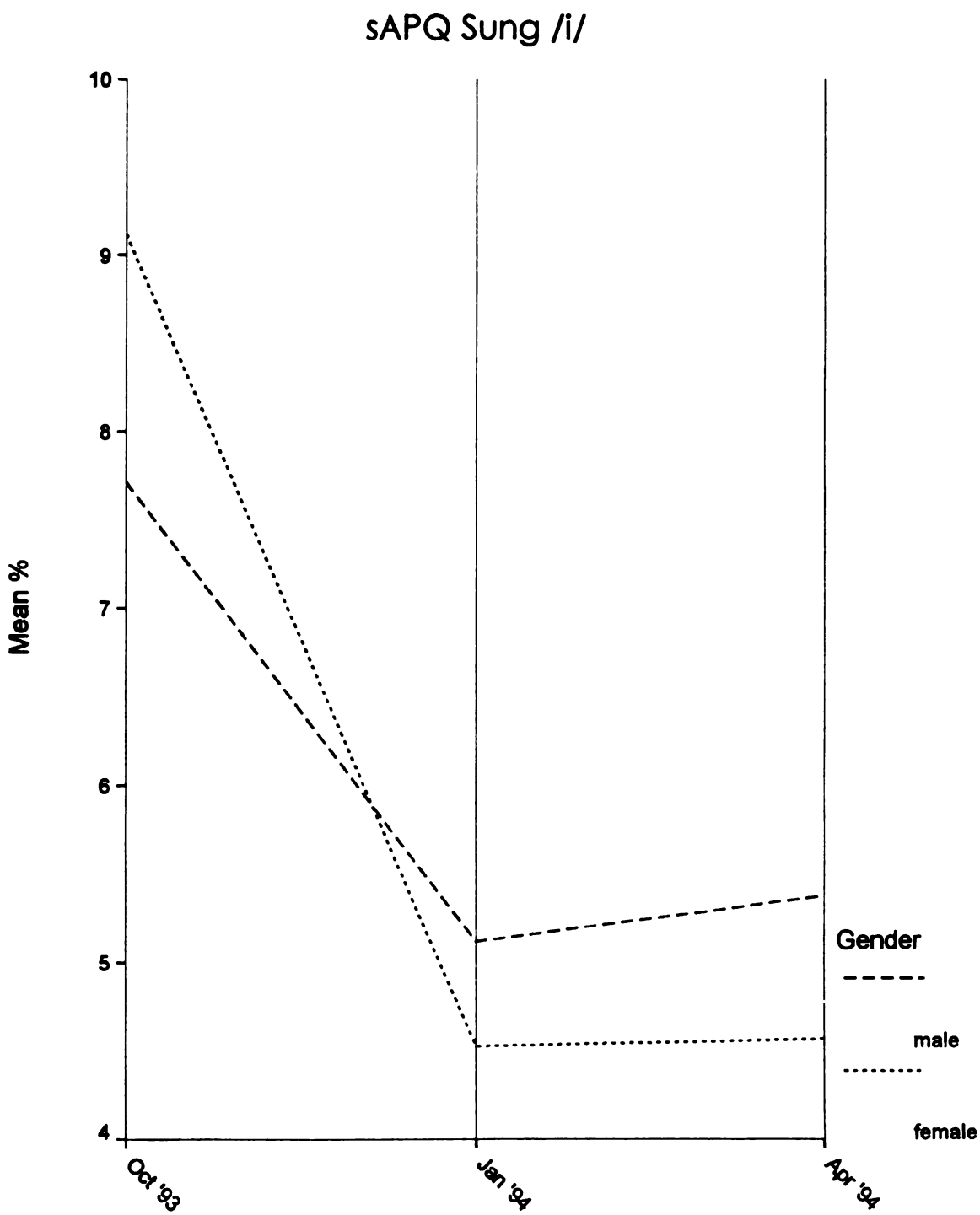

sAPQ Sung /i/
10
9
8
7
6
5
4
Mean %
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 68

APPENDIX U.5

vAm SUNG /i/

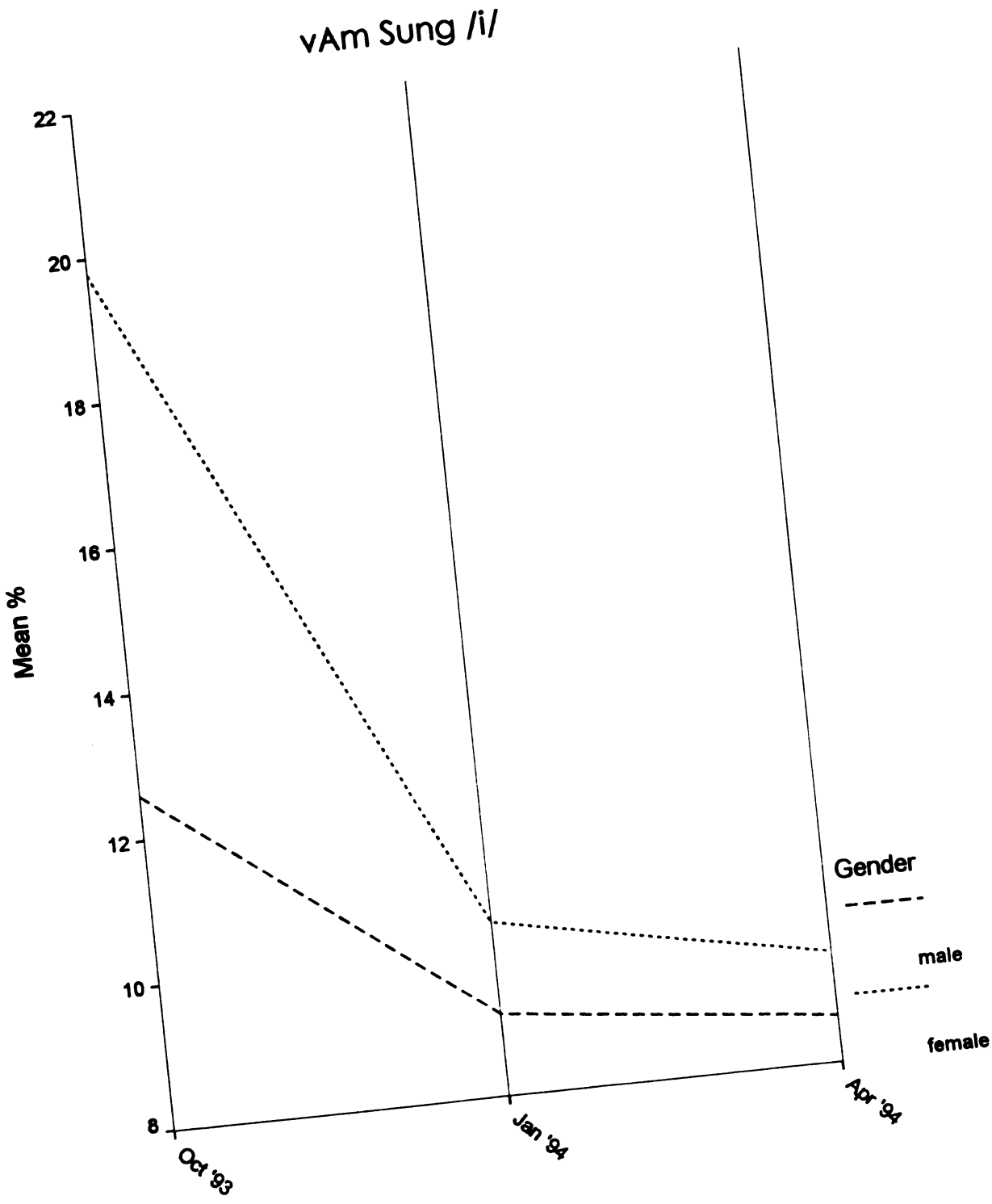

vAm Sung /i/
22
20
18
16
14
12
10
8
Mean %
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 69

APPENDIX V.1

NHR SUNG /i/

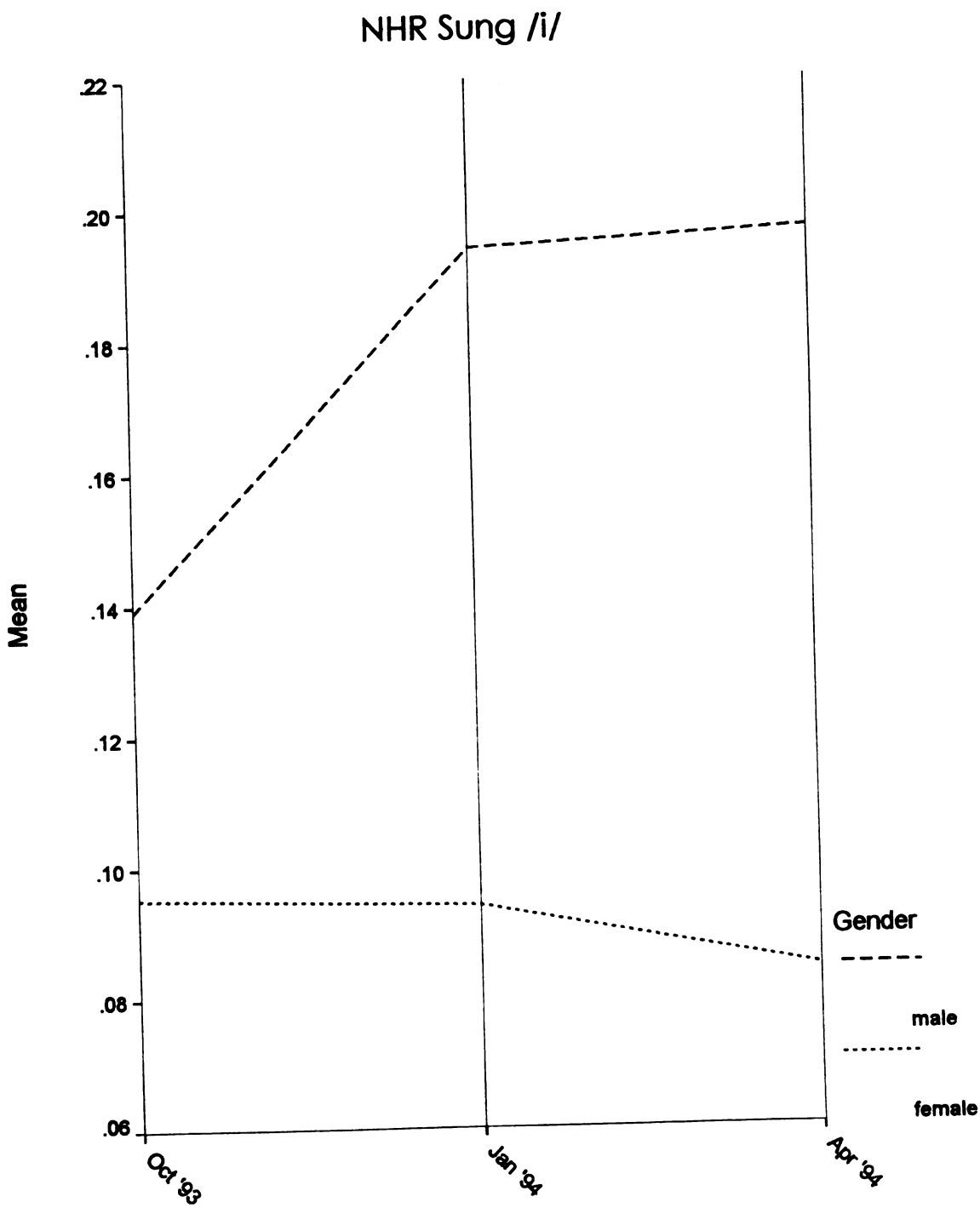

NHR Sung /i/
Mean
.22
.20
.18
.16
.14
.12
.10
.08
.06
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 70

APPENDIX V.2

VTI SUNG /i/

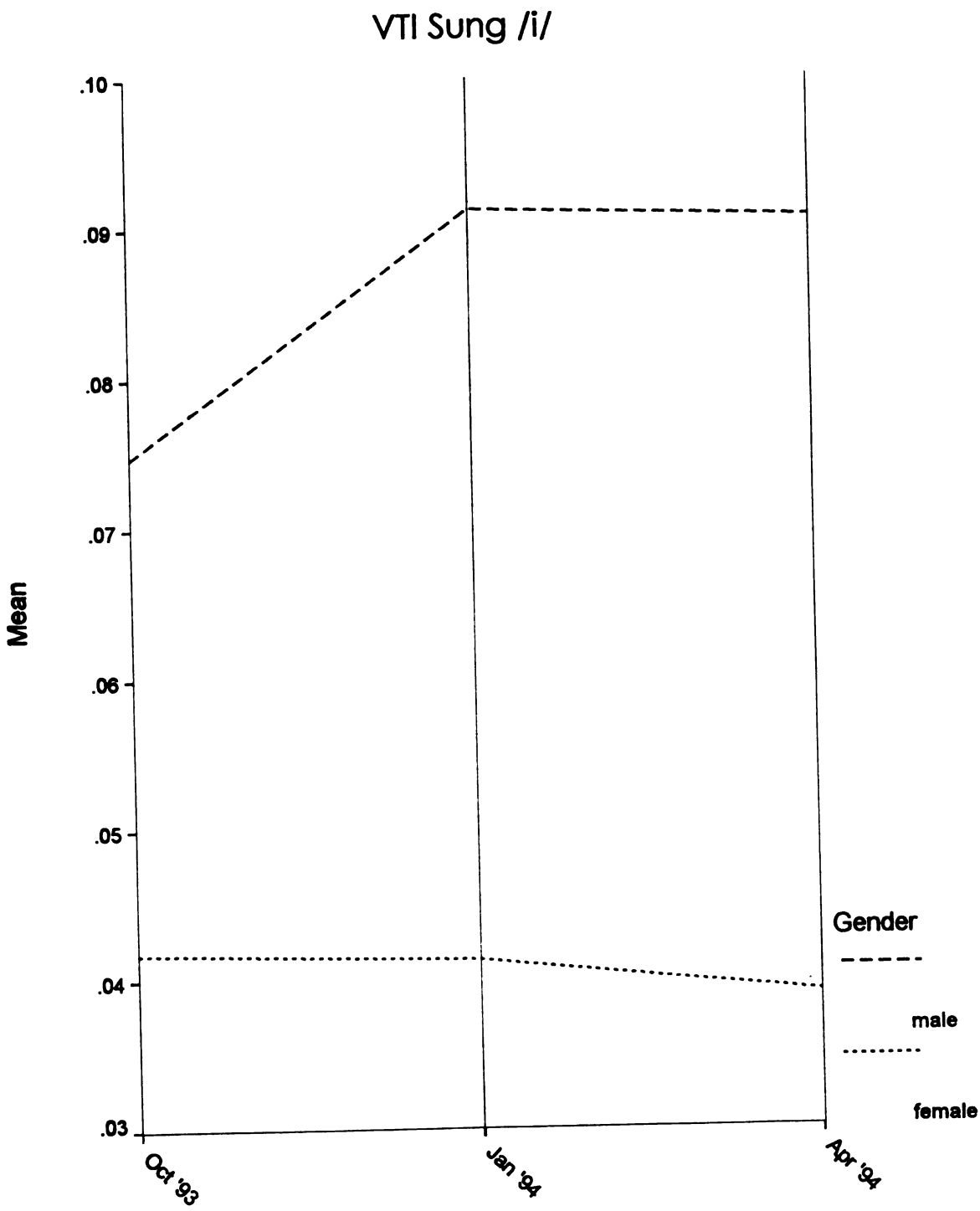

VTI Sung /i/
.10
.09
.08
.07
.06
.05
.04
.03
Mean
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 71

APPENDIX V.3

SPI SUNG /i/

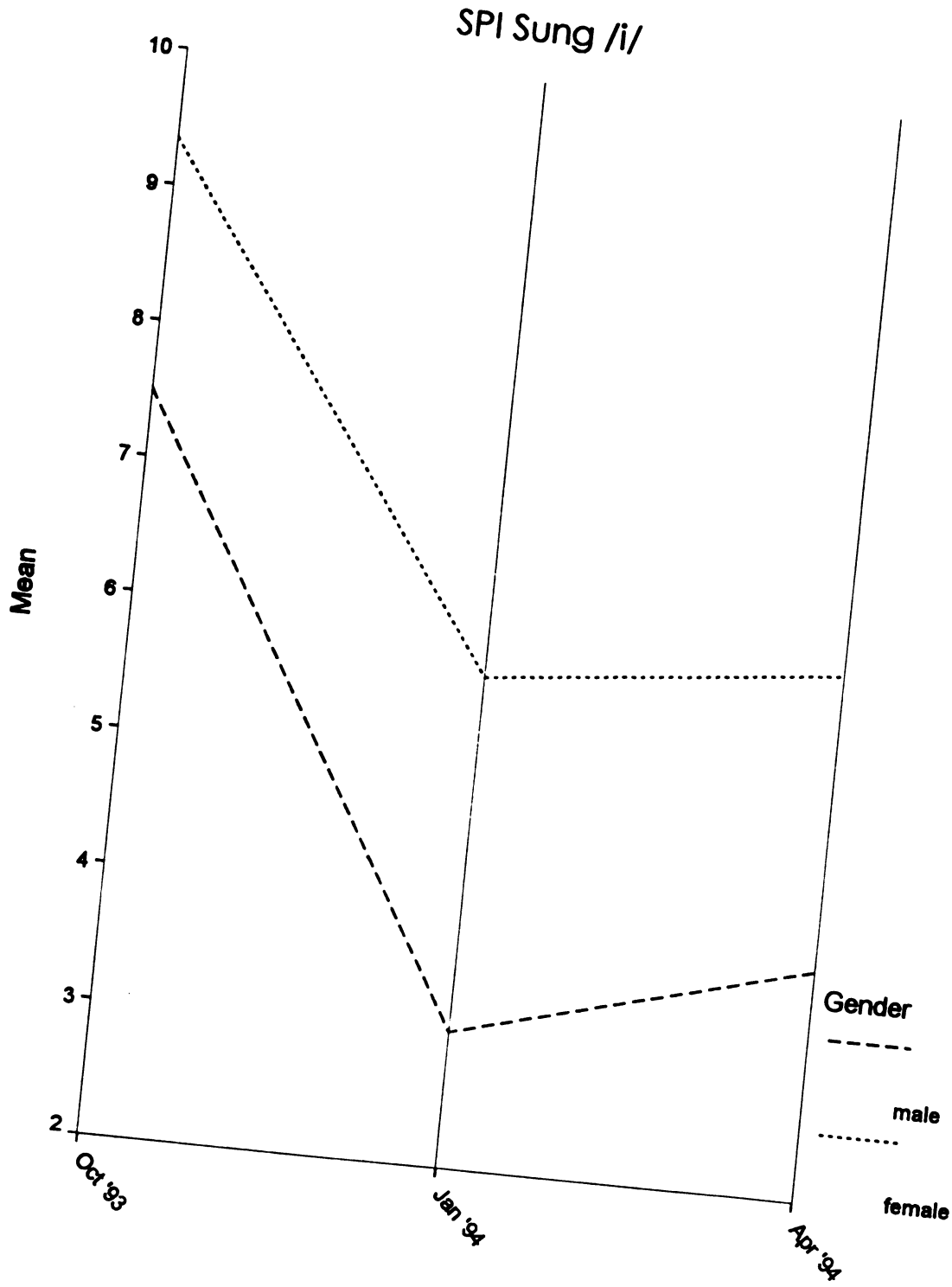

SPI Sung /i/
Mean
10
9
8
7
6
5
4
3
2
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 72

APPENDIX W.1

FTRI SUNG /i/

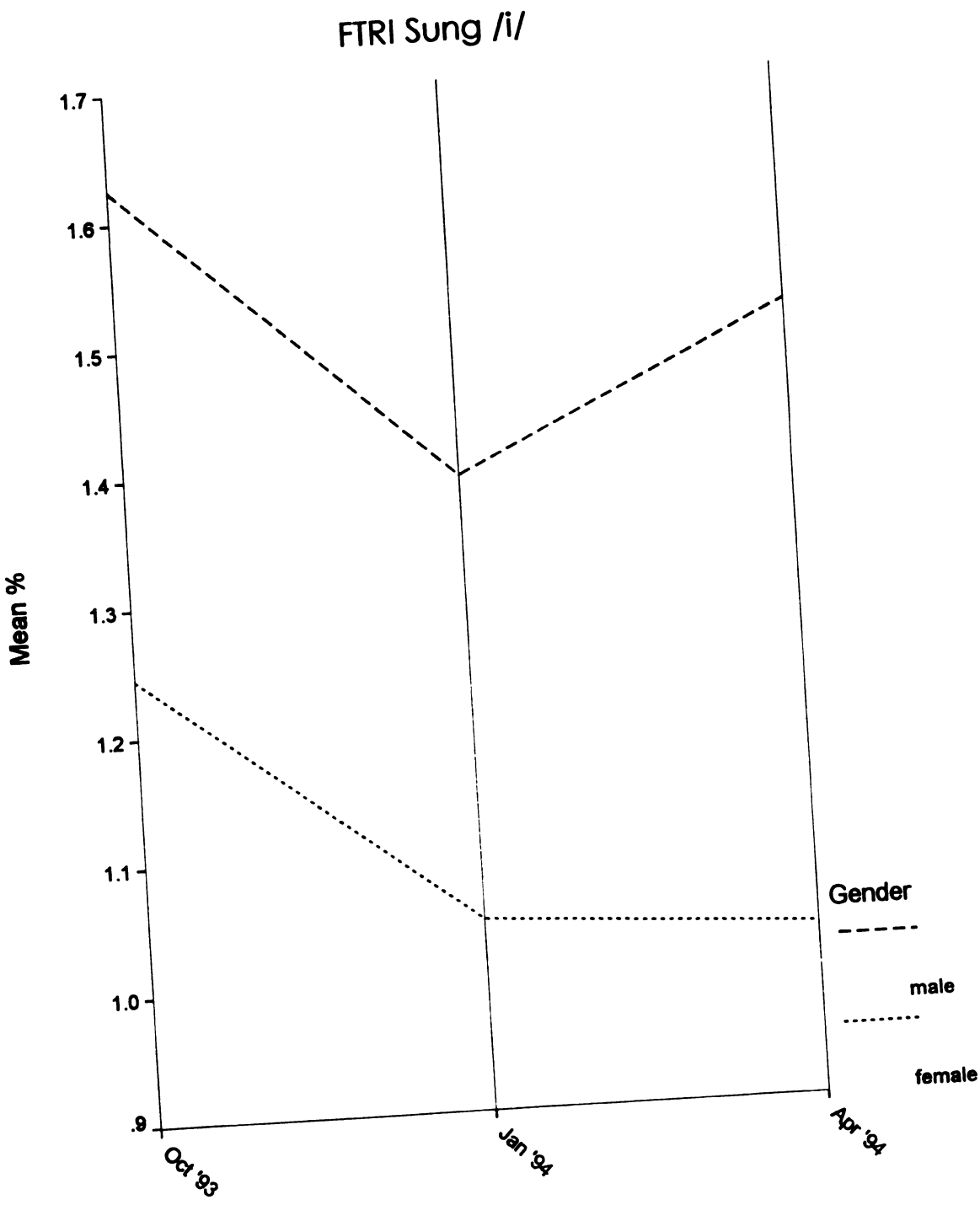

FTRI Sung /i/
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
Mean %
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 73

APPENDIX W.2

ATRI SUNG /i/

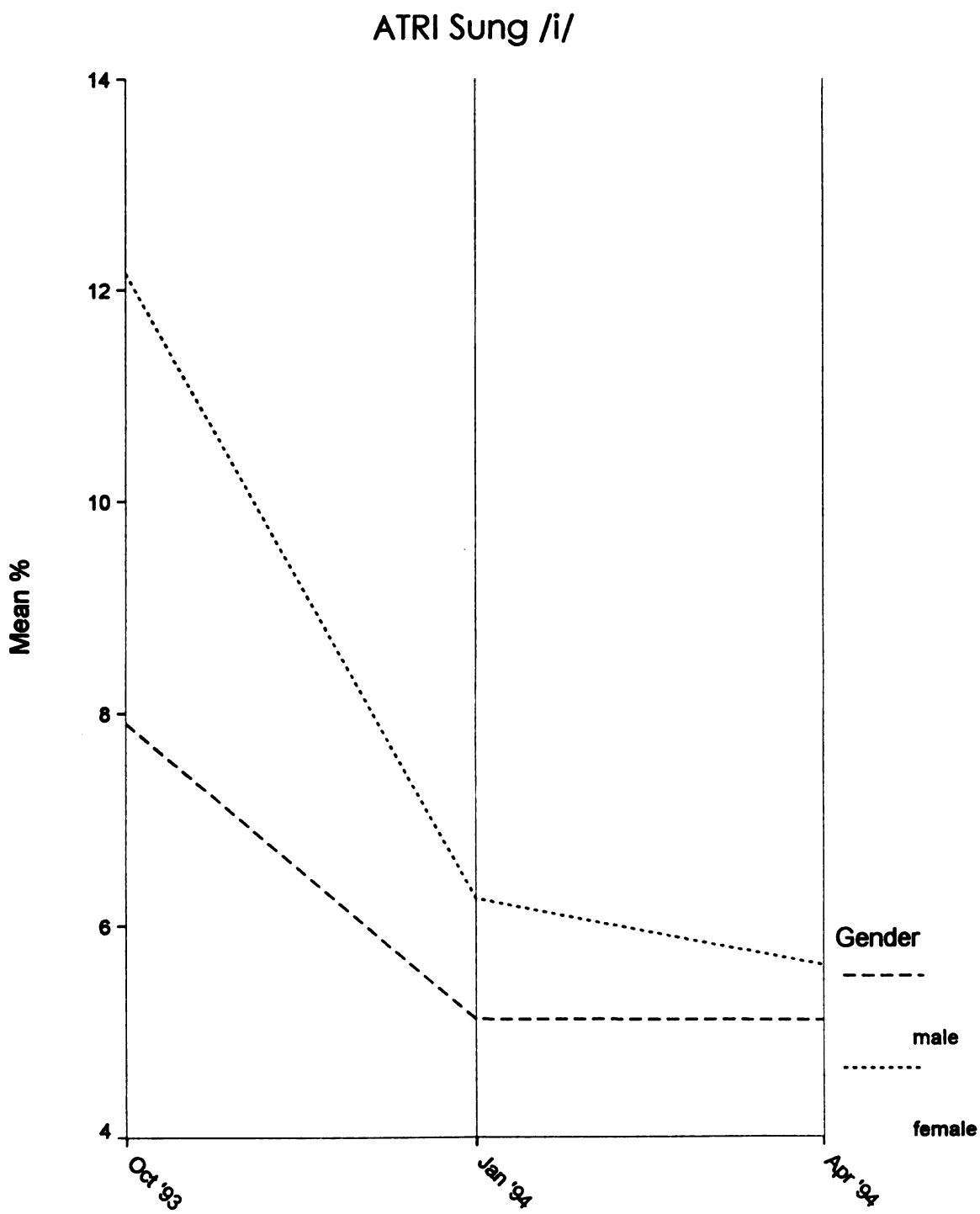

ATRI Sung /i/
14
12
10
8
6
4
Mean %
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 74

APPENDIX W.3

Fftr SUNG /i/

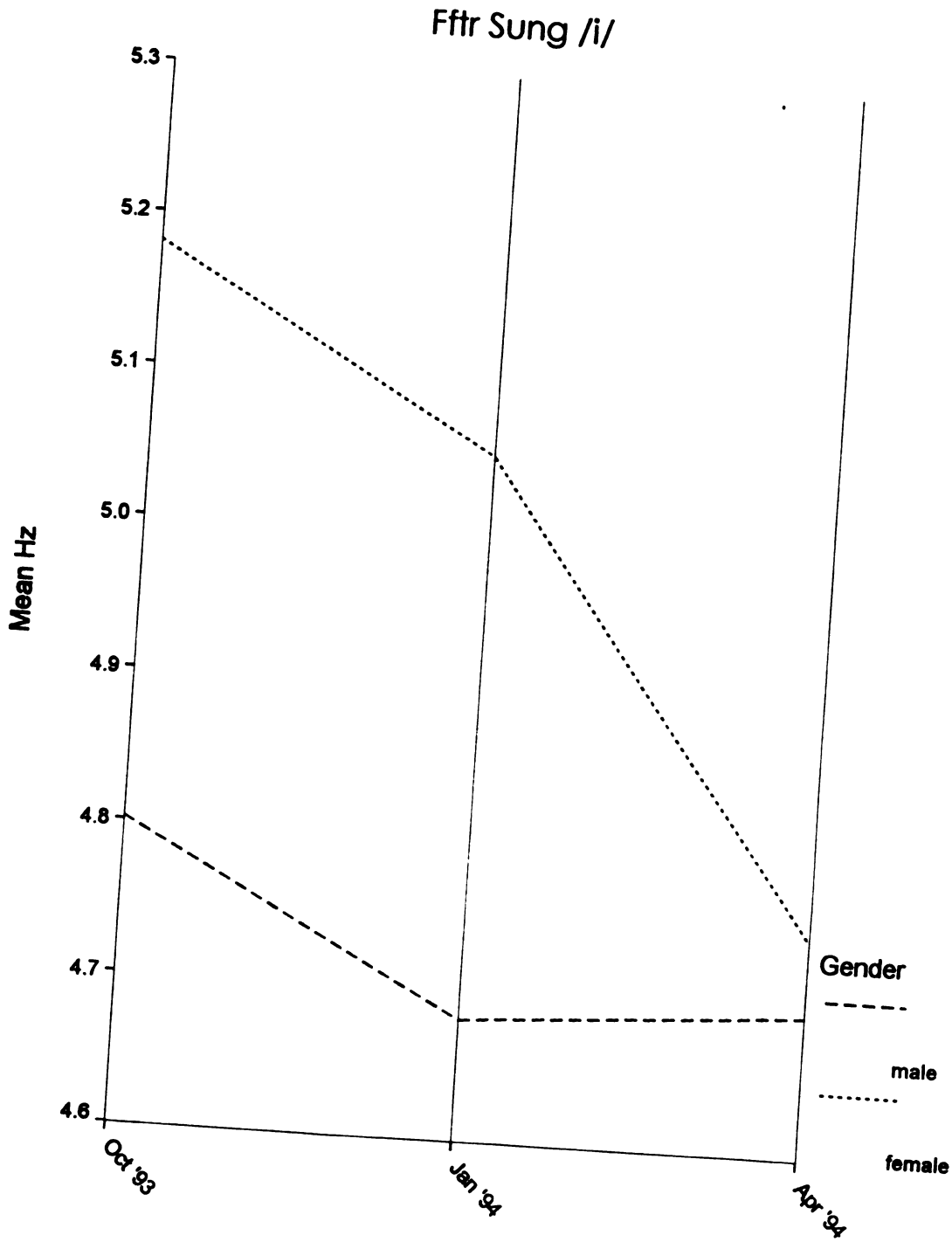

Fftr Sung /i/
5.3
5.2
5.1
5.0
4.9
4.8
4.7
4.6
Mean Hz
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 75

APPENDIX W.4

Fatr SUNG /i/

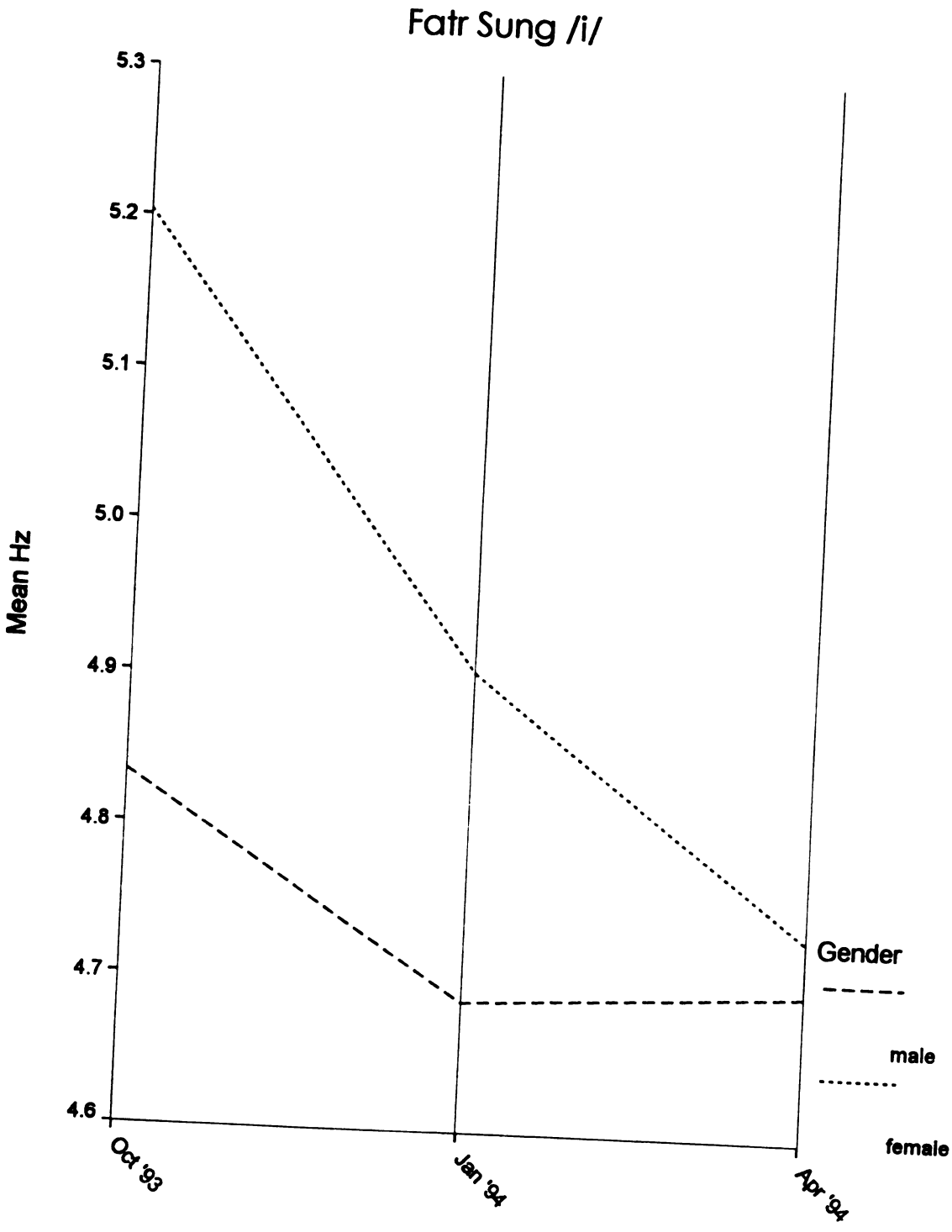

Fatr Sung /i/
5.3
5.2
5.1
5.0
4.9
4.8
4.7
4.6
Mean Hz
Oct '93
Jan '94
Apr '94
Gender
male
female

FIGURE 76

APPENDIX X.1

Fo SPOKEN /u/

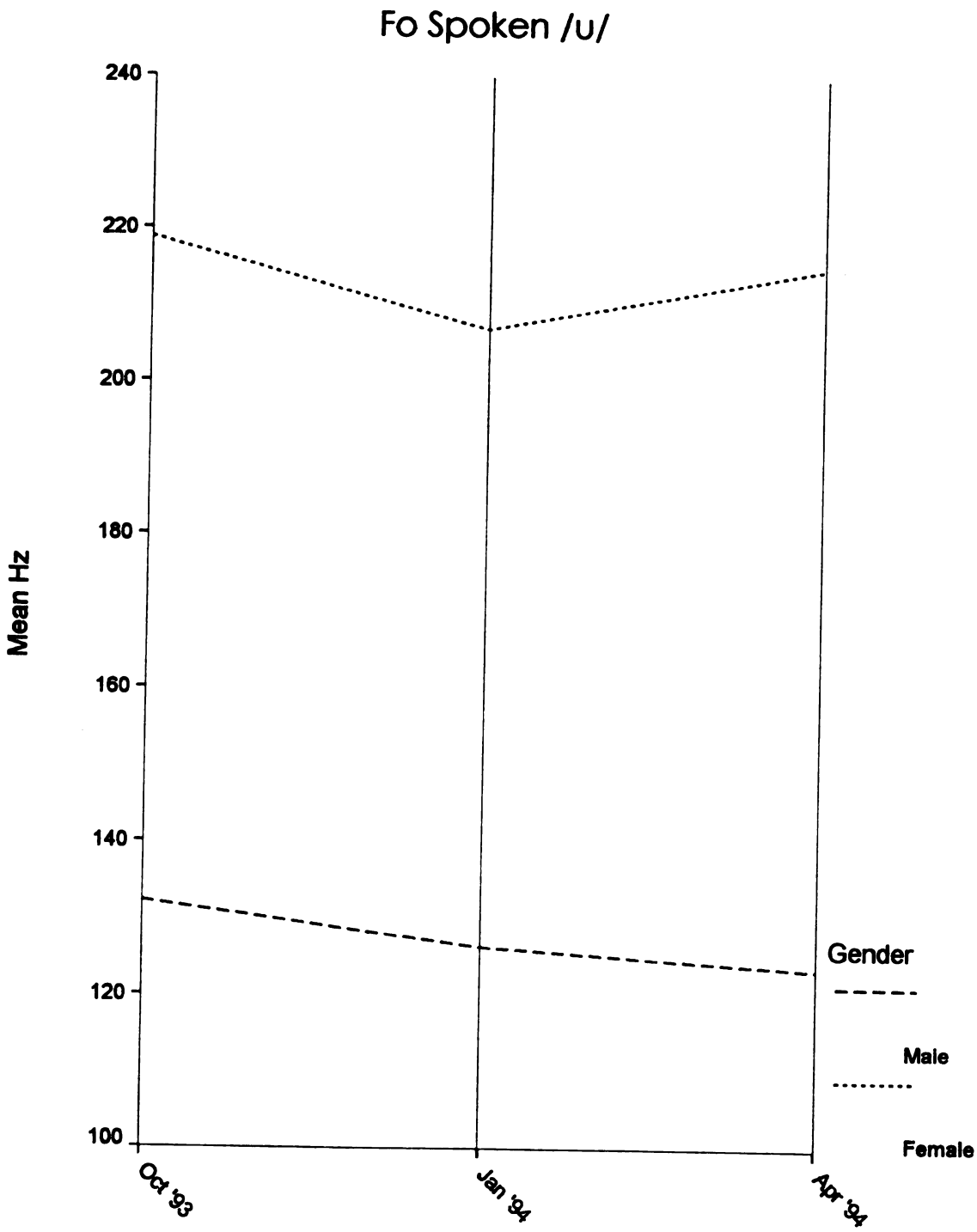

Fo Spoken /u/
240
220
200
180
160
140
120
100
Mean Hz
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 77

APPENDIX X.2

Jita SPOKEN /u/

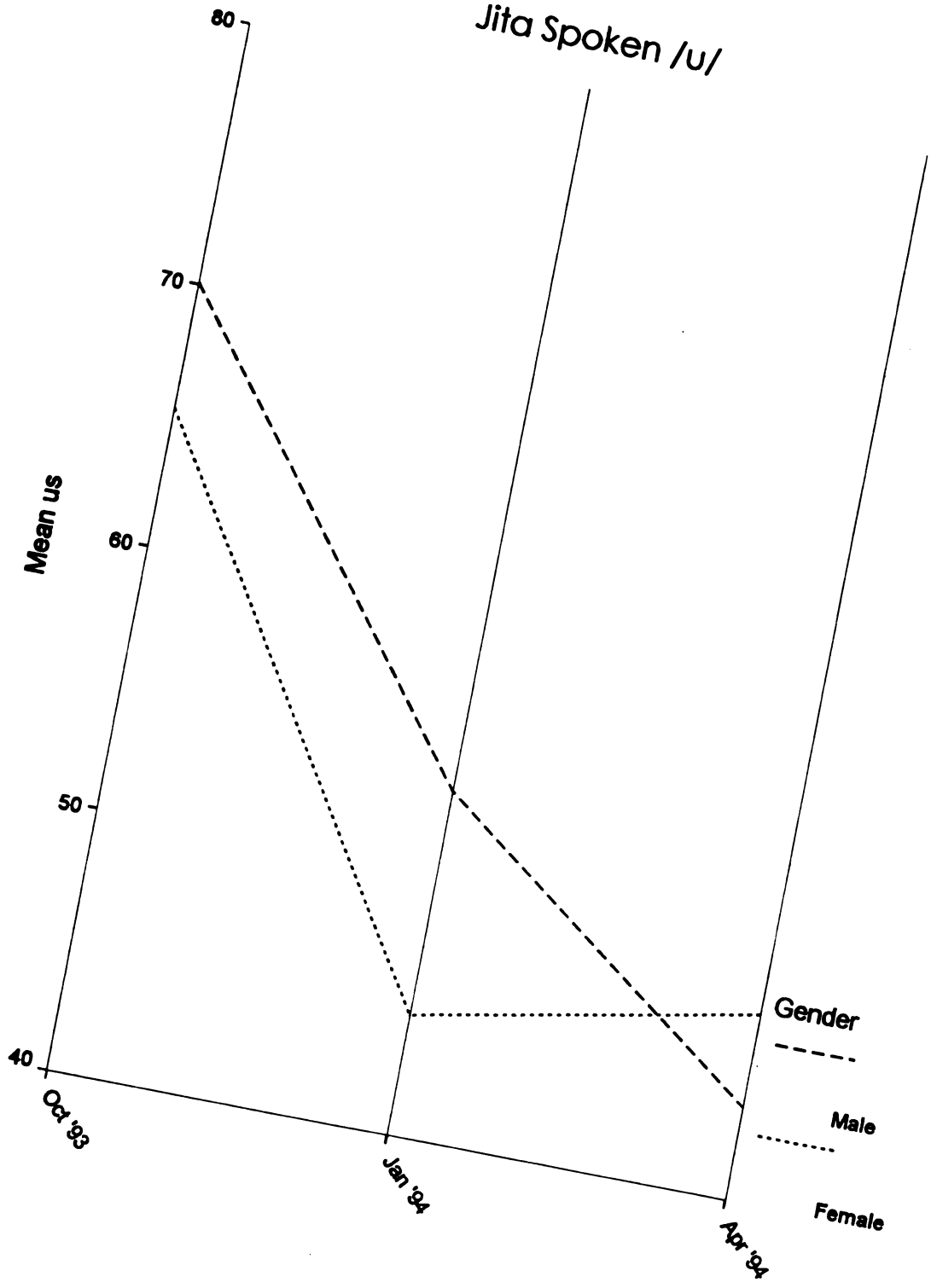

Jita Spoken /u/
80
70
60
50
40
Mean us
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 78

APPENDIX X.3

Jitt SPOKEN /u/

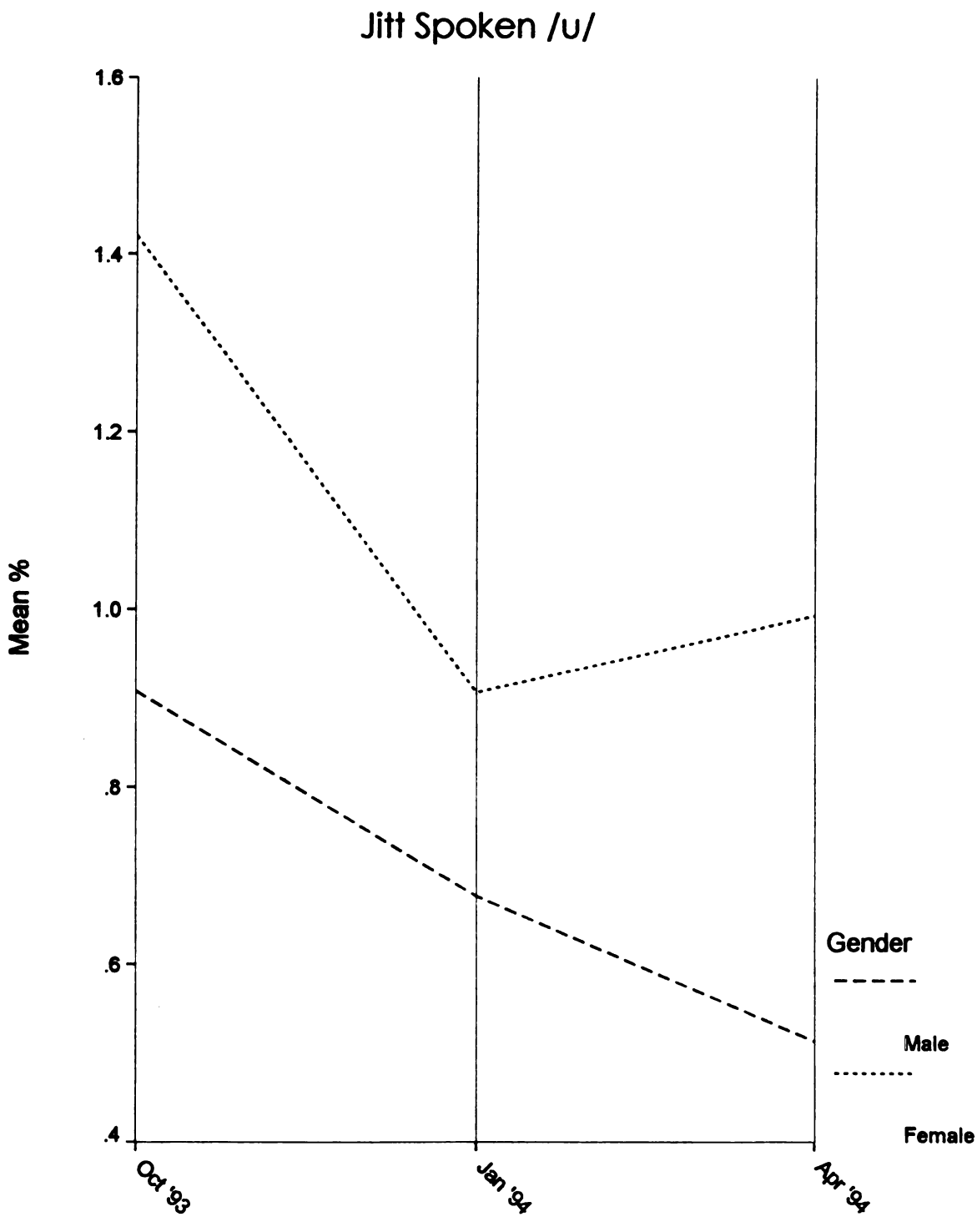

Jitt Spoken /u/
Mean %
1.6
1.4
1.2
1.0
.8
.6
.4
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 79

APPENDIX X.4

RAP SPOKEN /u/

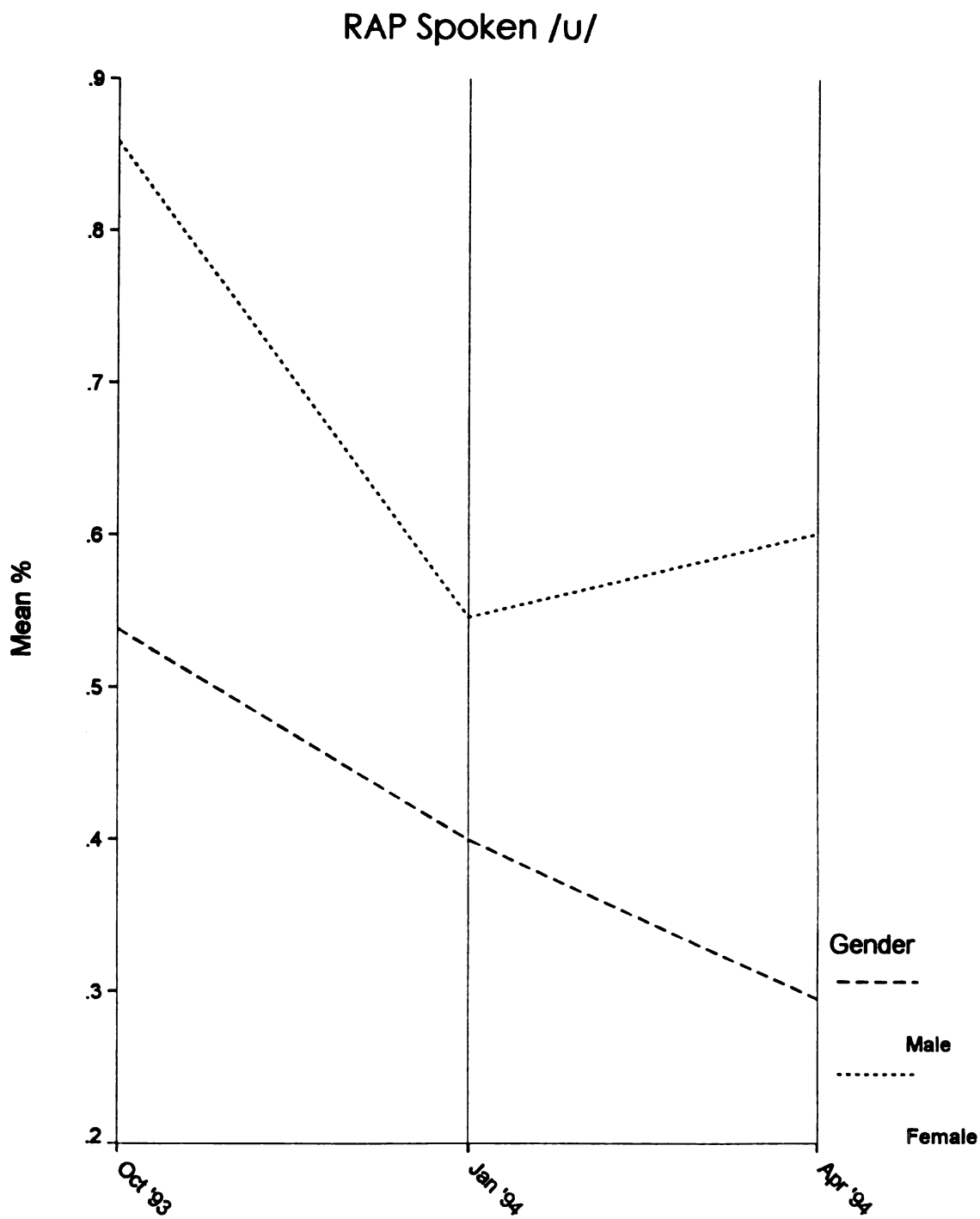

RAP Spoken /u/
Mean %
.9
.8
.7
.6
.5
.4
.3
.2
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 80

APPENDIX X.5

PPQ SPOKEN /u/

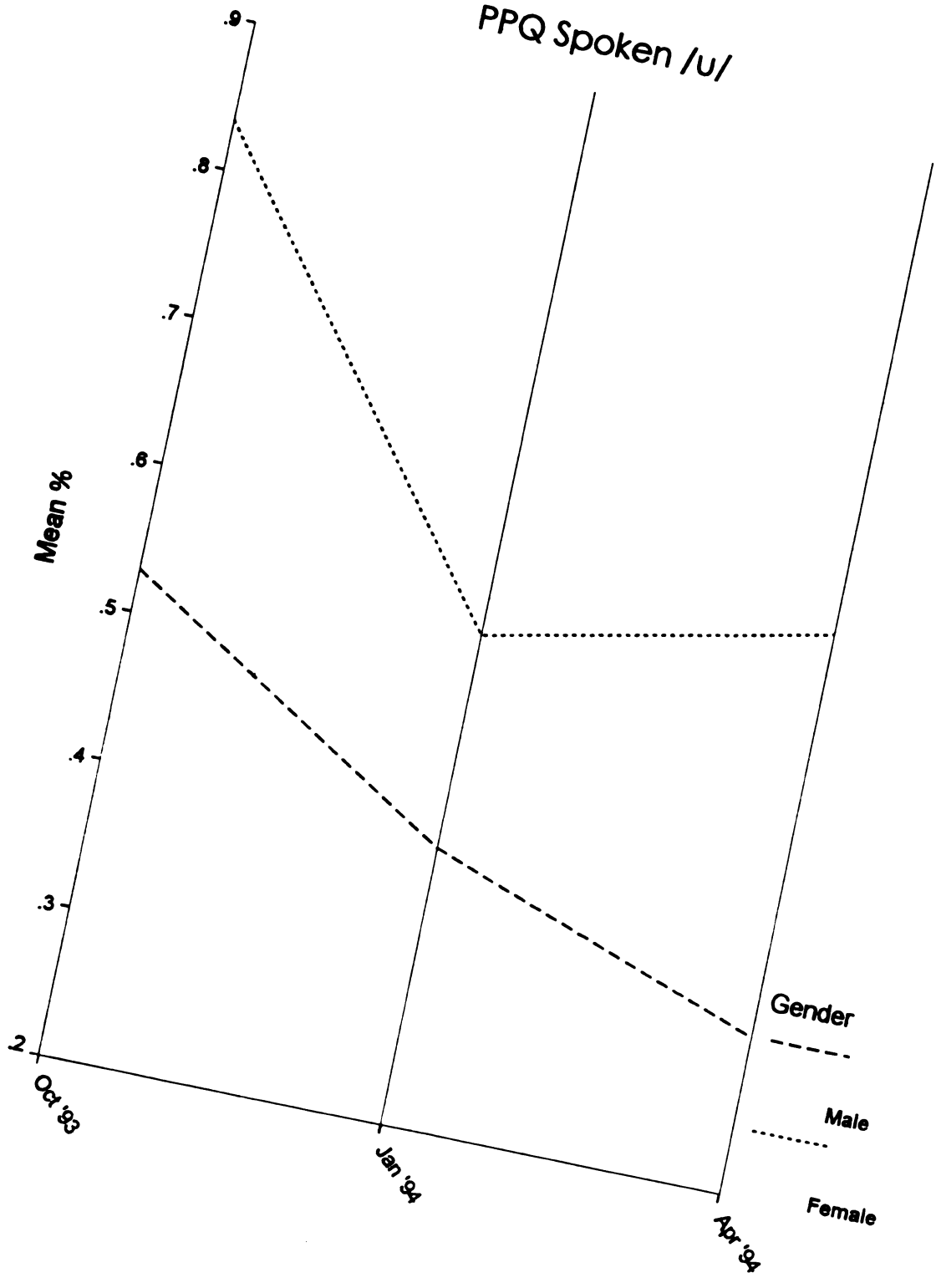

PPQ Spoken /u/
Mean %
.9
.8
.7
.6
.5
.4
.3
.2
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 81

APPENDIX X.6

sPPQ SPOKEN /u/

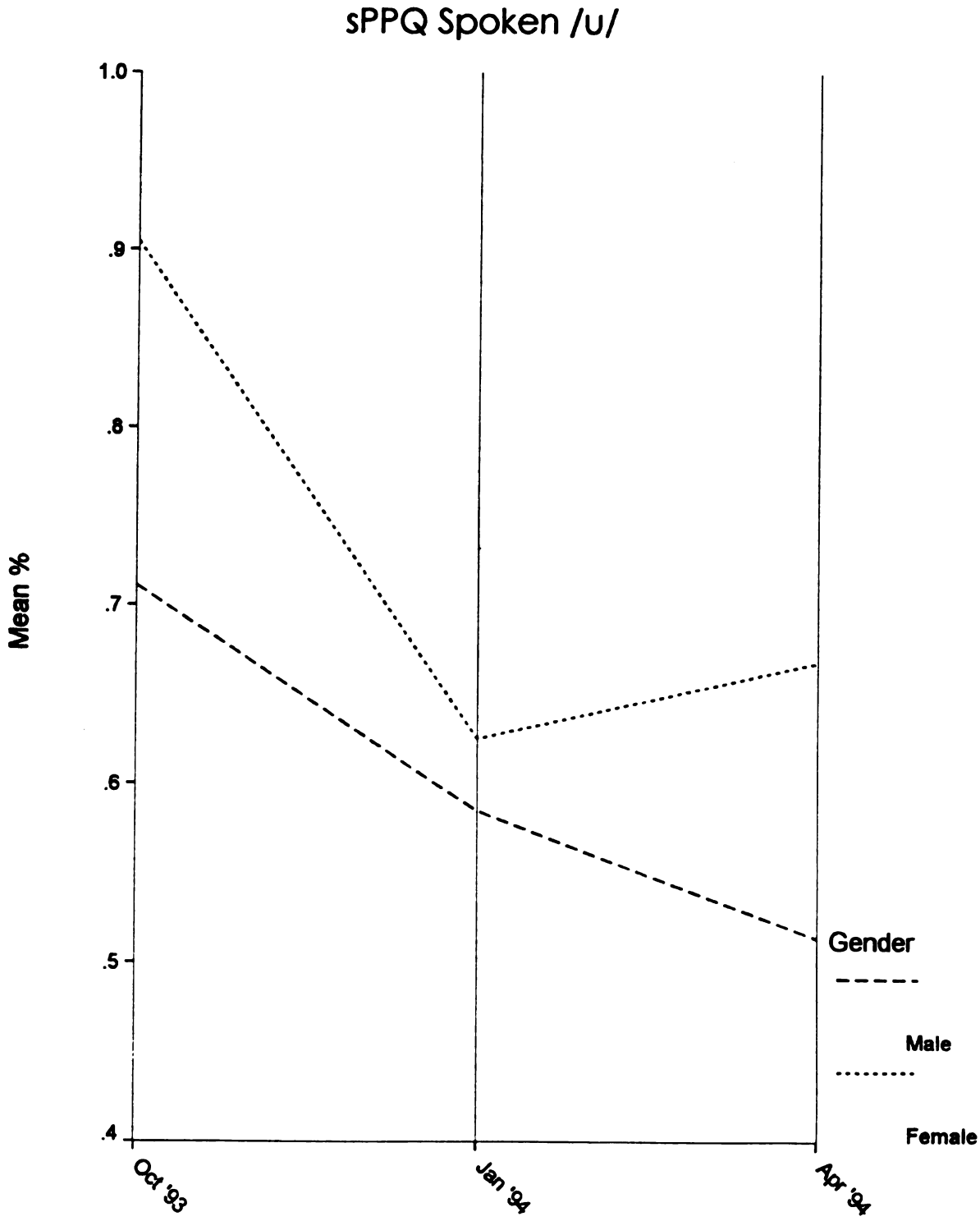

sPPQ Spoken /u/
1.0
.9
.8
.7
.6
.5
.4
Mean %
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 82

APPENDIX X.7

vFo SPOKEN /u/

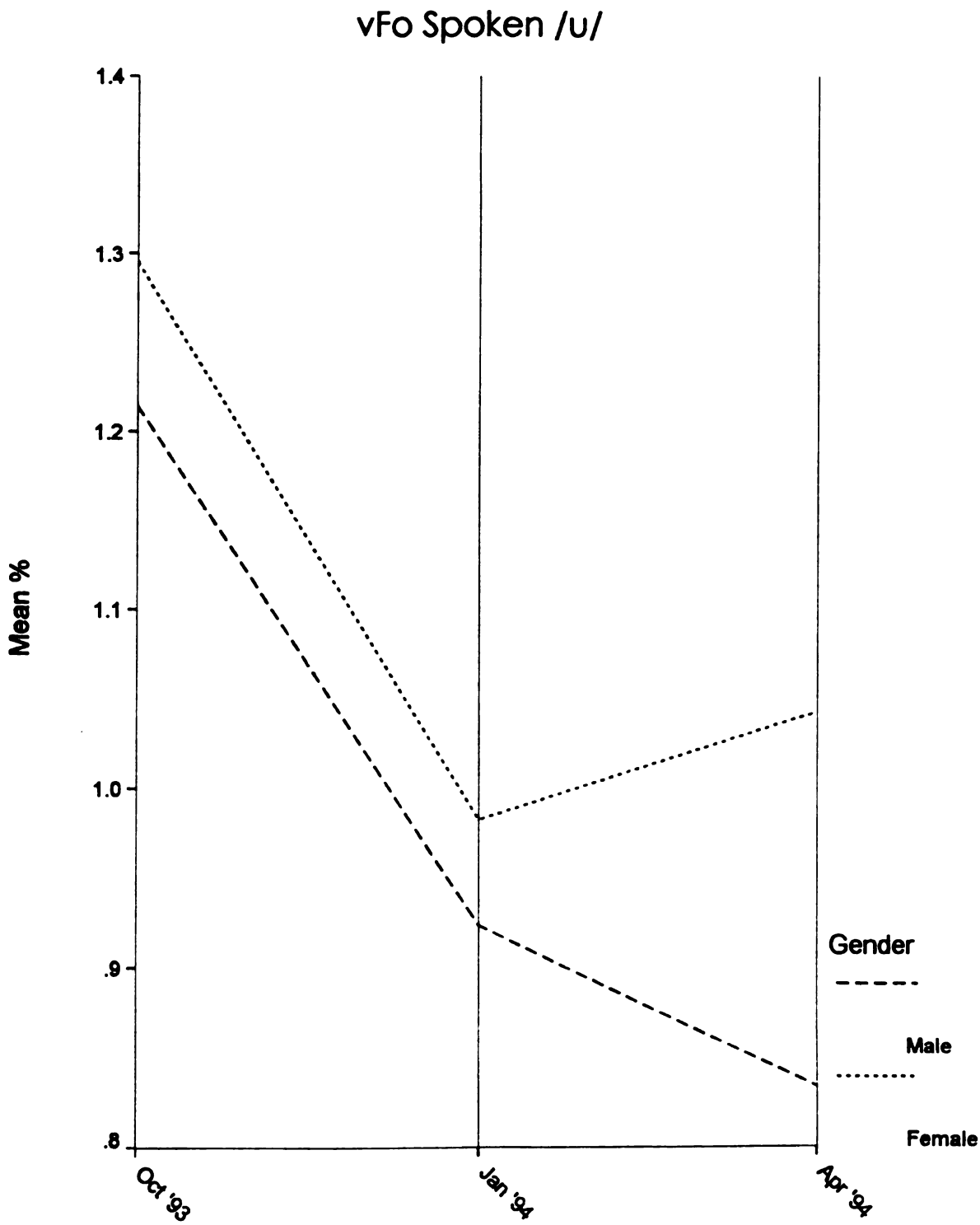

vFo Spoken /u/
1.4
1.3
1.2
1.1
1.0
.9
.8
Mean %
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 83

APPENDIX Y.1

ShdB SPOKEN /u/

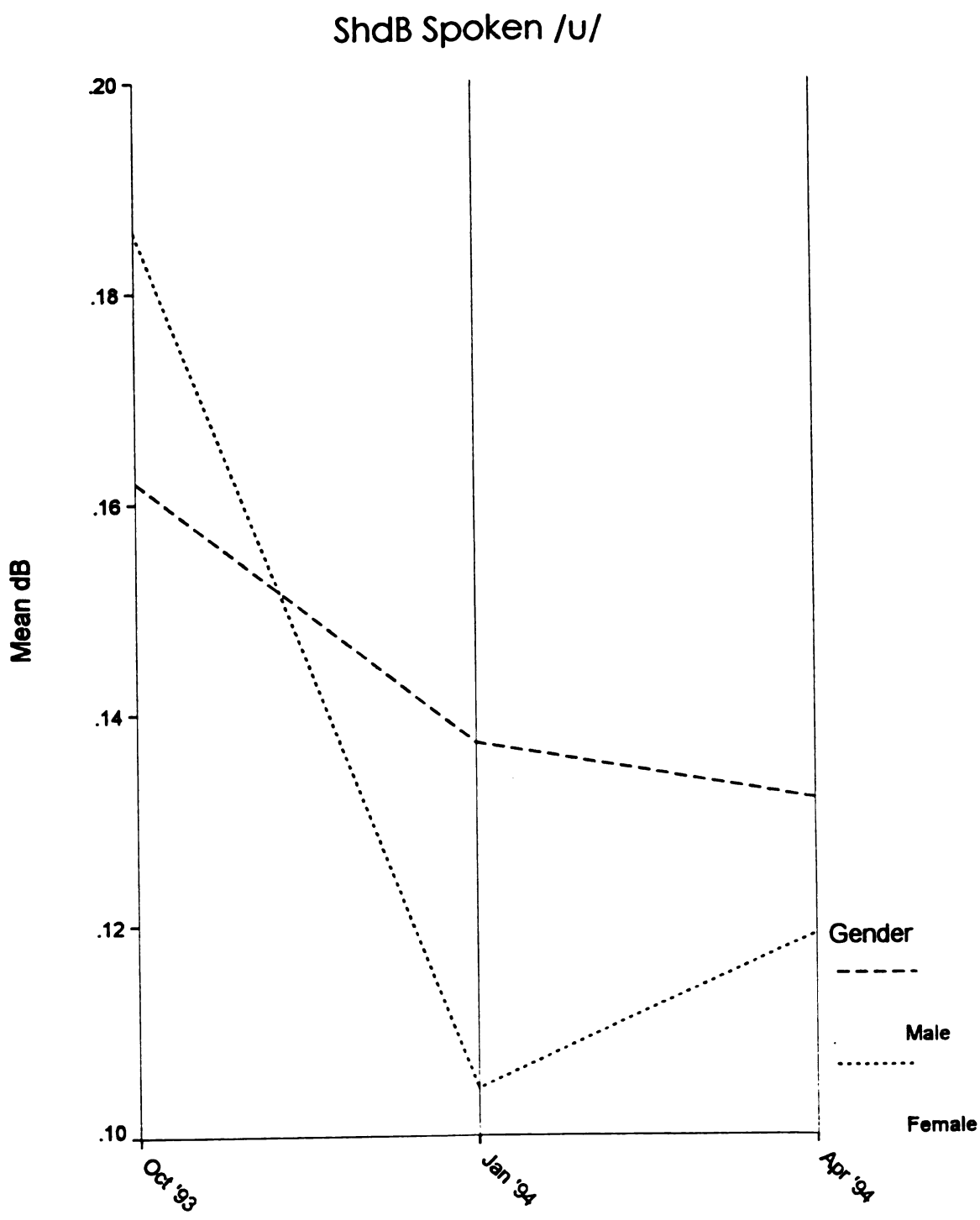

ShdB Spoken /u/
.20
.18
.16
.14
.12
.10
Mean dB
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 84

APPENDIX Y.2

Shim SPOKEN /u/

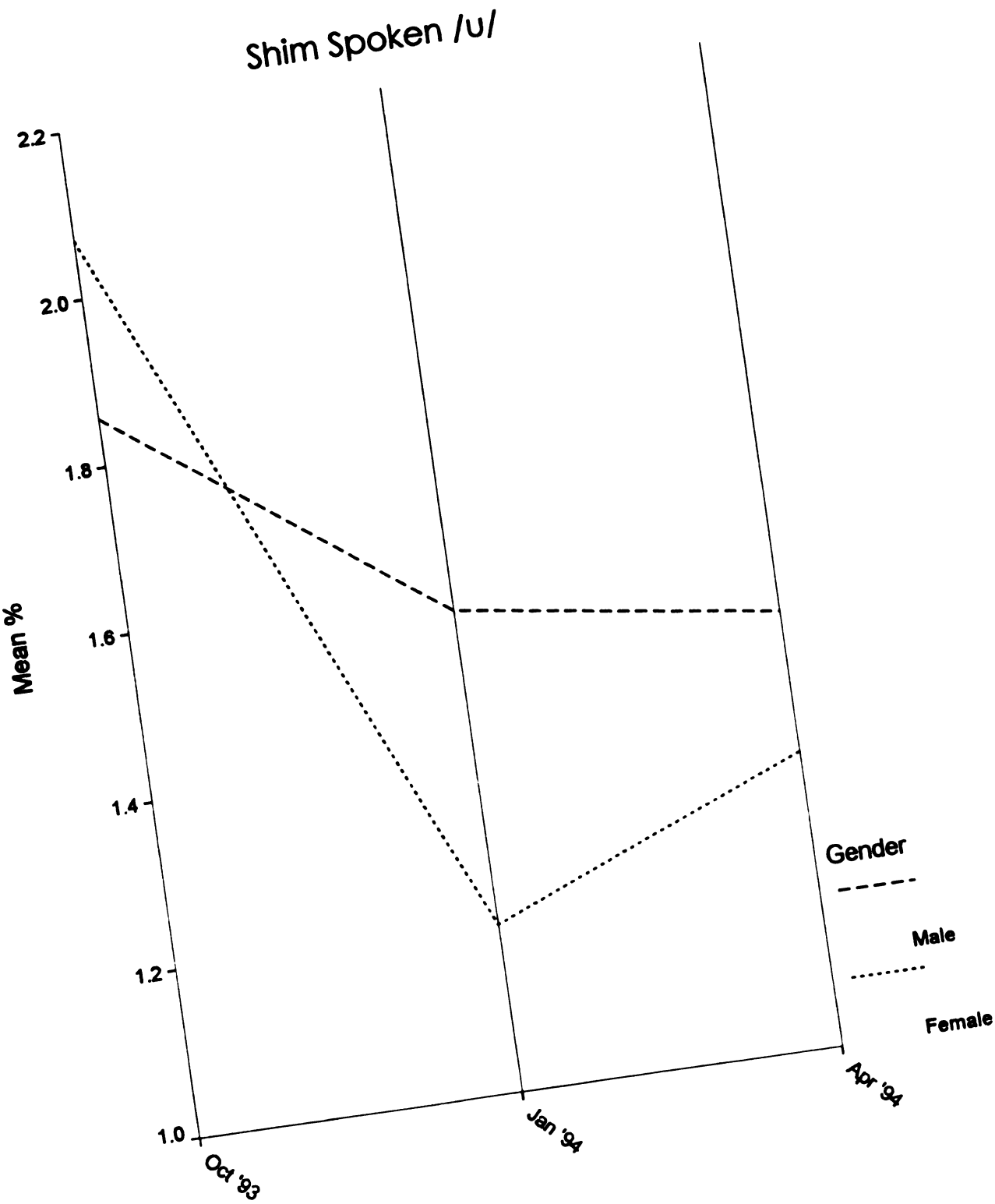

Shim Spoken /U/
2.2
2.0
1.8
1.6
1.4
1.2
1.0
Mean %
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 85

APPENDIX Y.3

APQ SPOKEN /u/

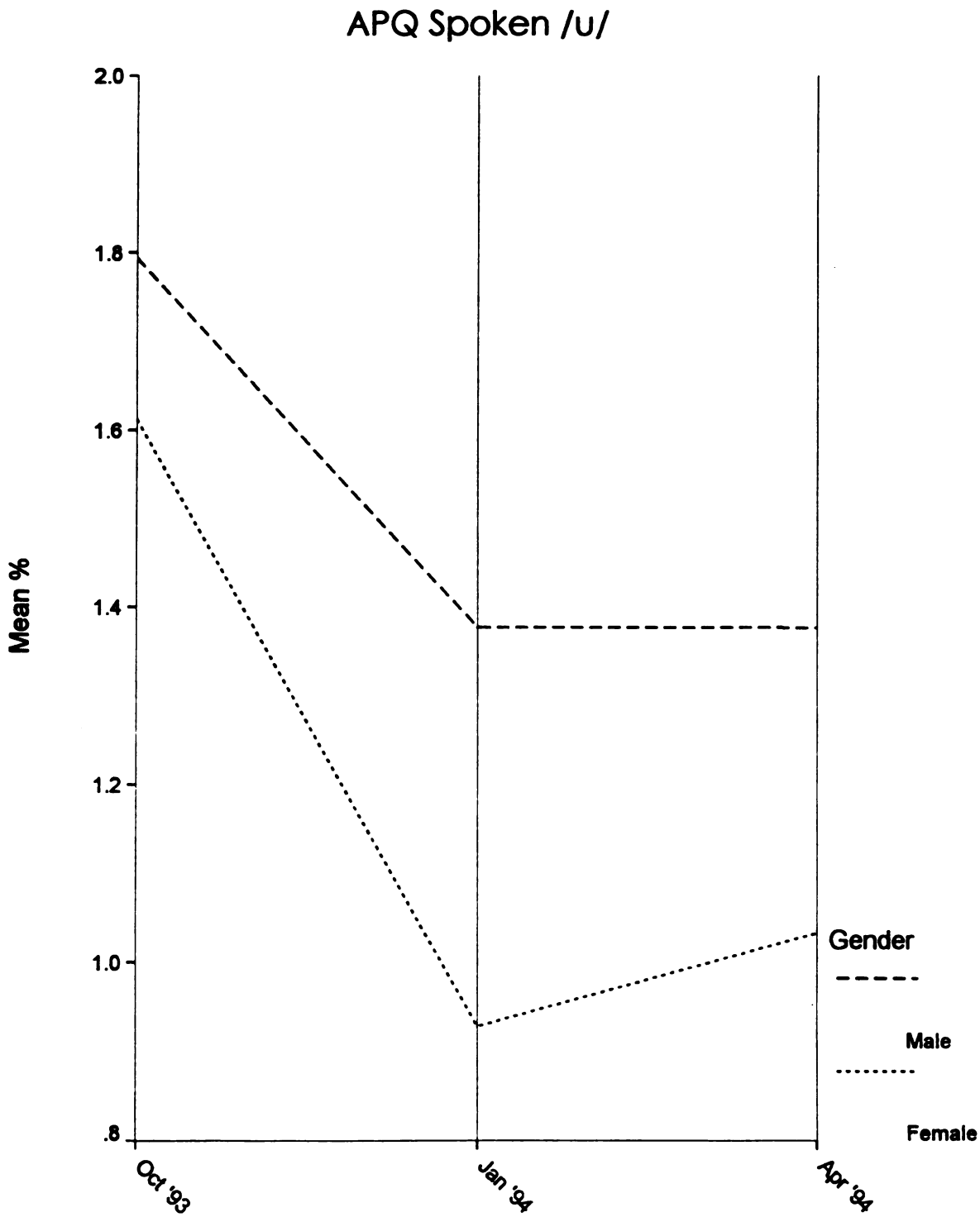

APQ Spoken /u/
2.0
1.8
1.6
1.4
1.2
1.0
.8
Mean %
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 86

APPENDIX Y.4

sAPQ SPOKEN /u/

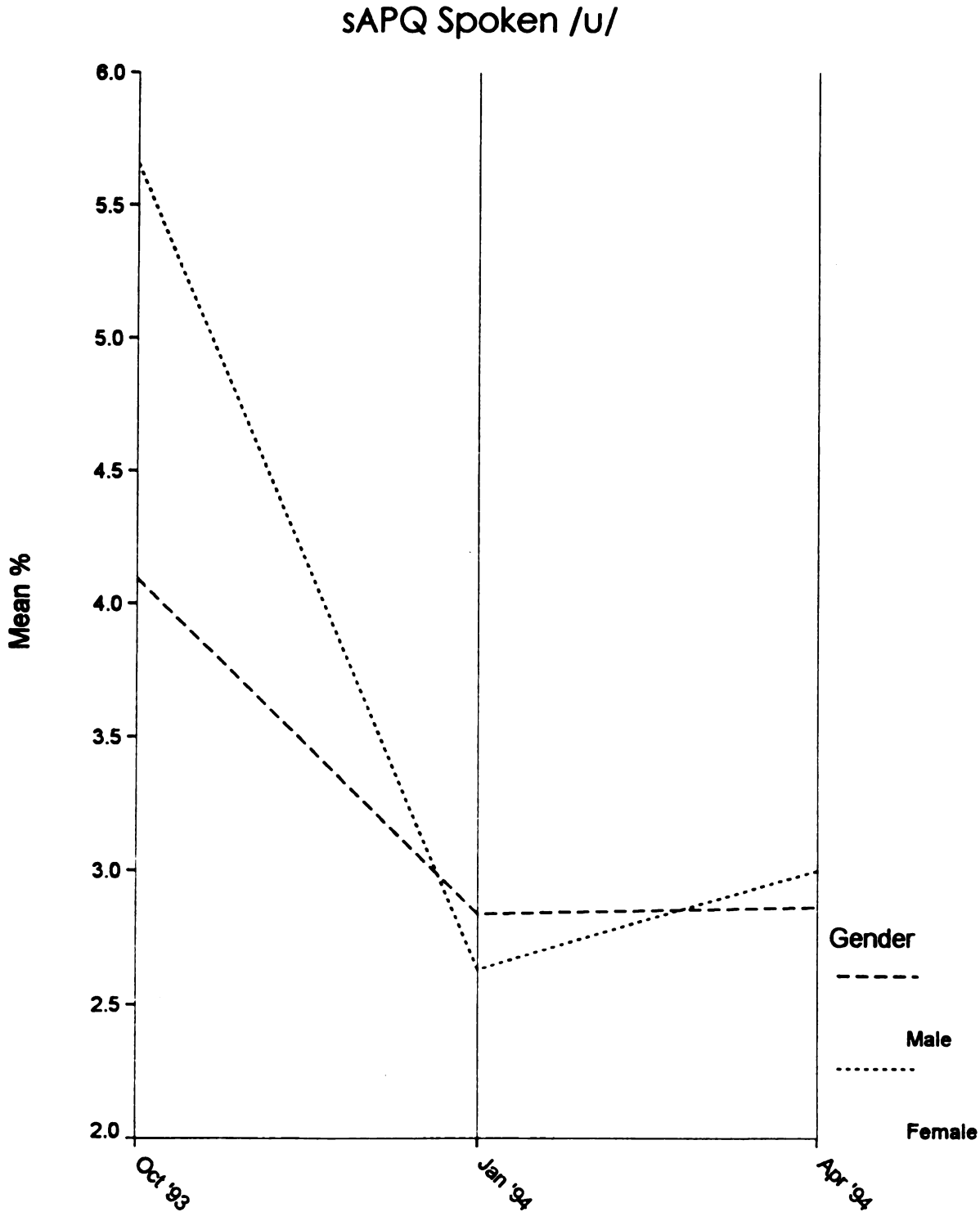

sAPQ Spoken /u/
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
Mean %
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 87

APPENDIX Y.5

vAm SPOKEN /u/

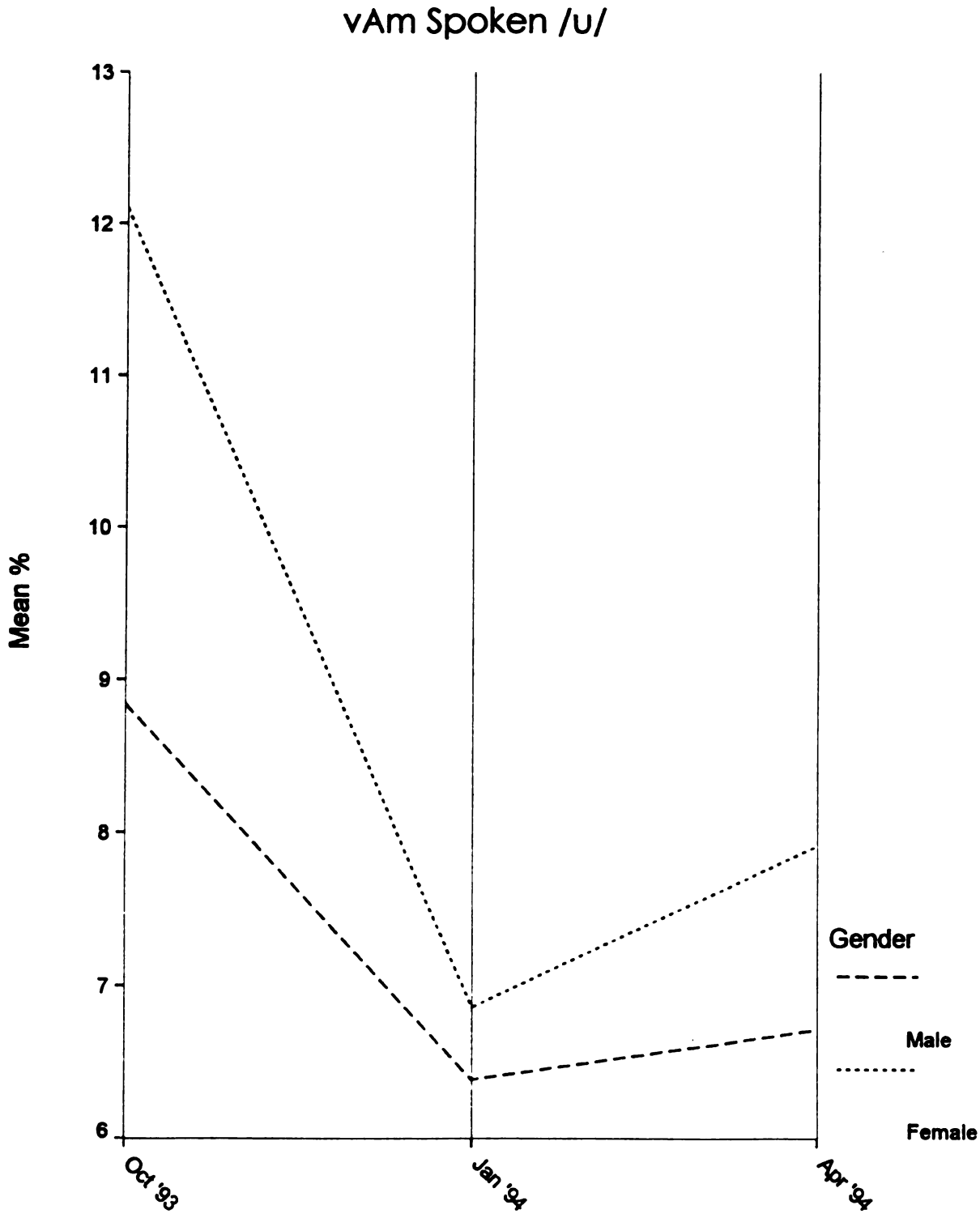

vAm Spoken /u/
Mean %
13
12
11
10
9
8
7
6
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 88

APPENDIX Z.1

NHR SPOKEN /u/

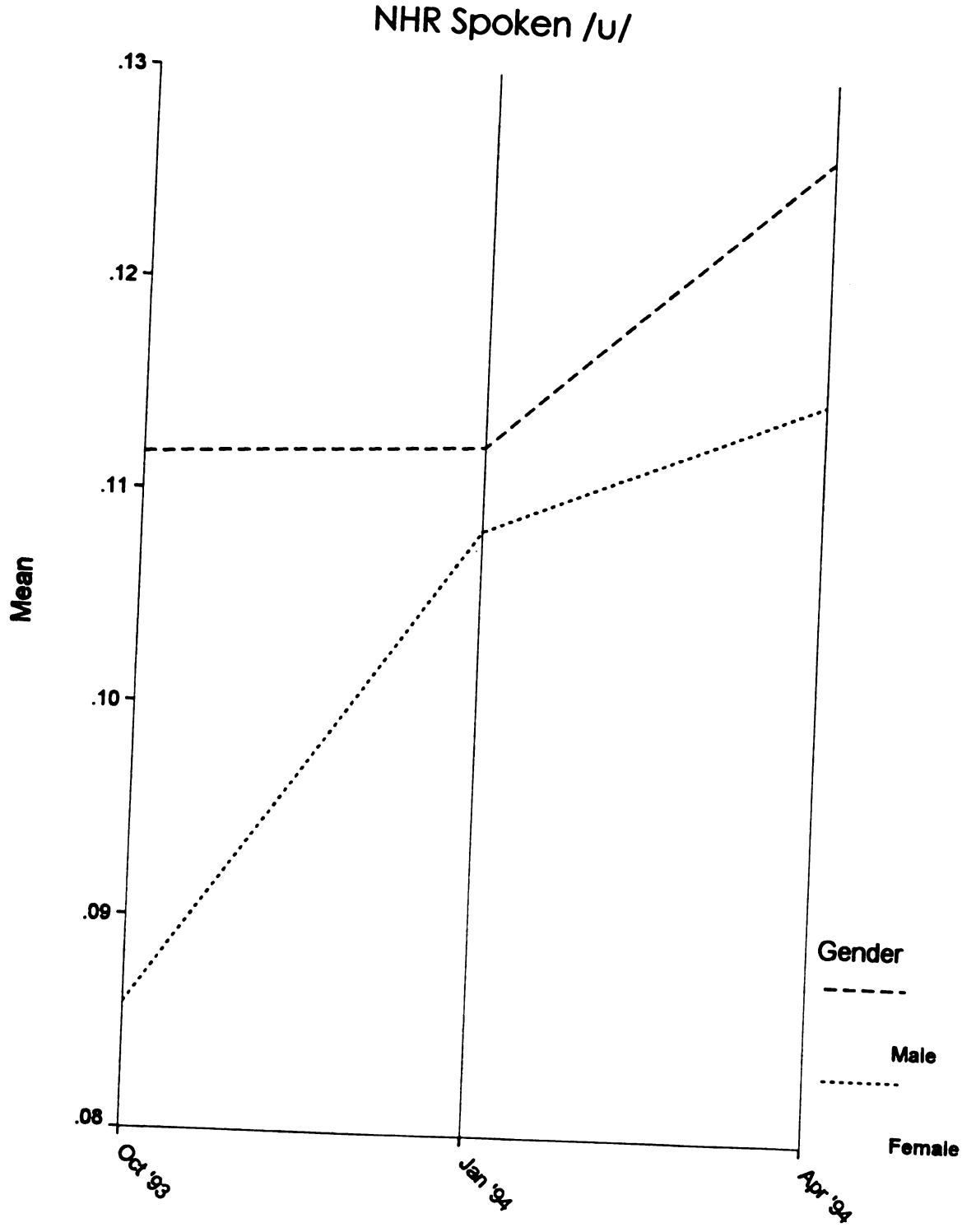

NHR Spoken /u/
.13
.12
.11
.10
.09
.08
Mean
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 89

APPENDIX Z.2

VTI SPOKEN /u/

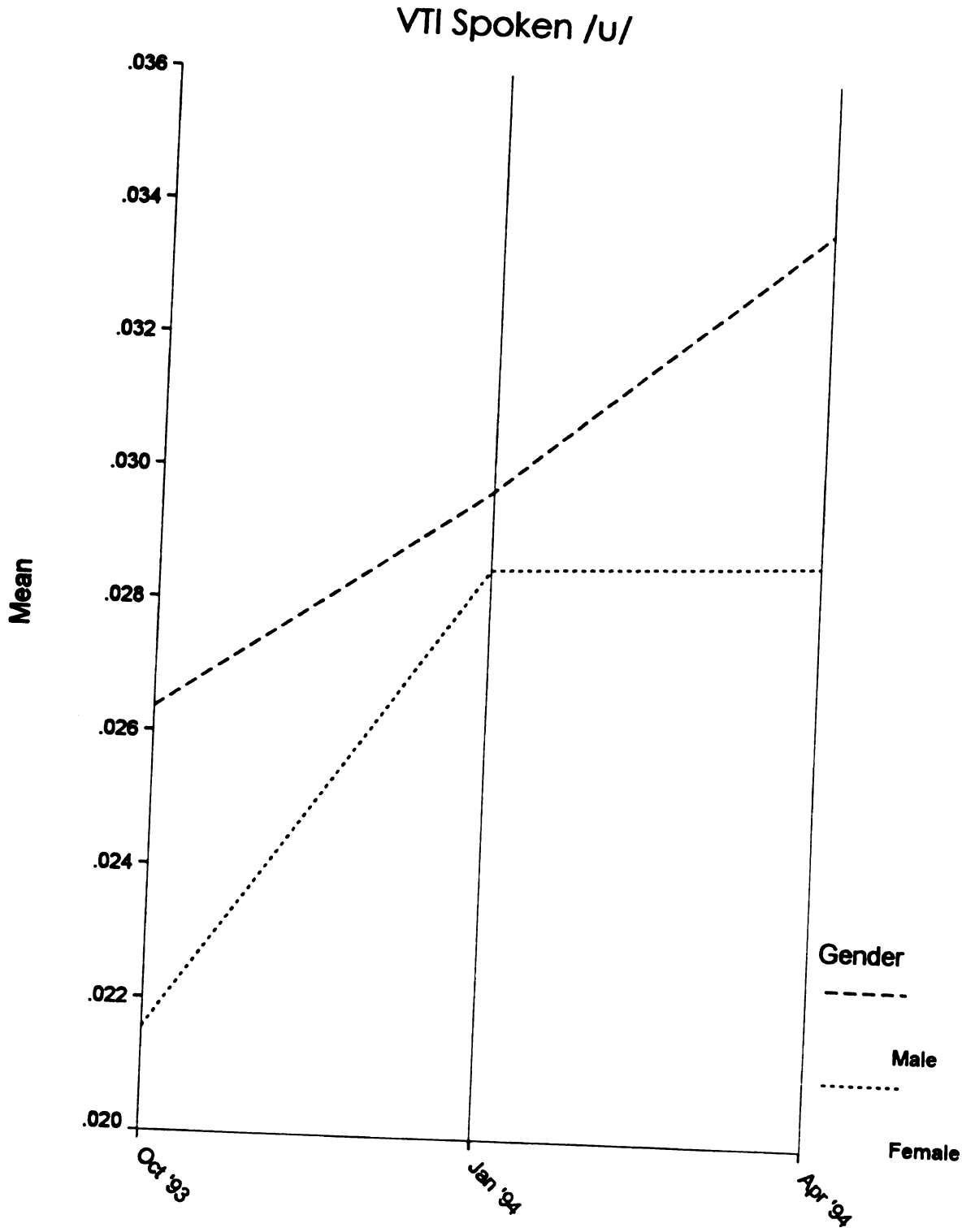

VTI Spoken /u/
.036
.034
.032
.030
.028
.026
.024
.022
.020
Mean
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 90

APPENDIX Z.3

SPI SPOKEN /u/

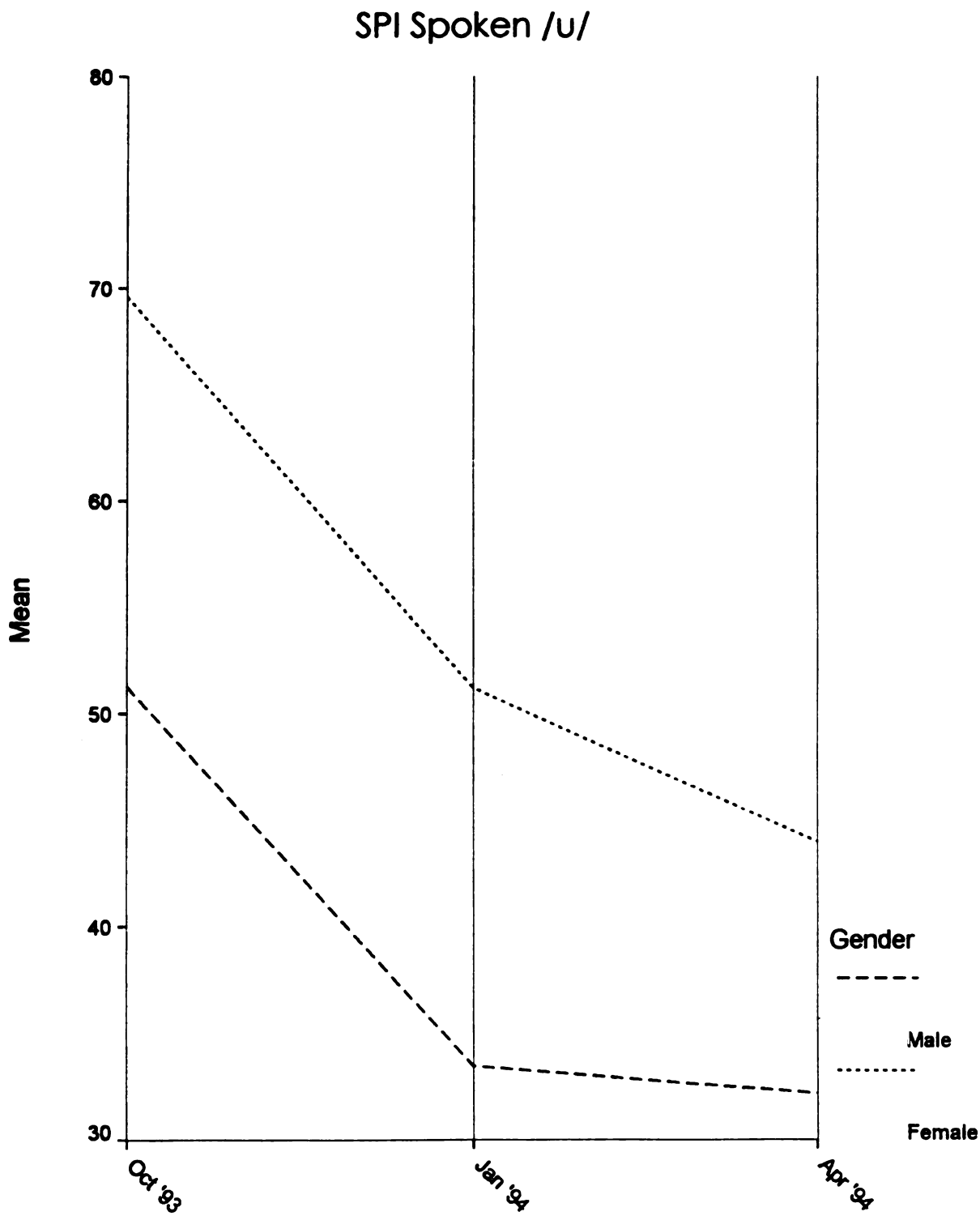

SPI Spoken /u/
80
70
60
50
40
30
Mean
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 91

APPENDIX AA.1

FTRI SPOKEN /u/

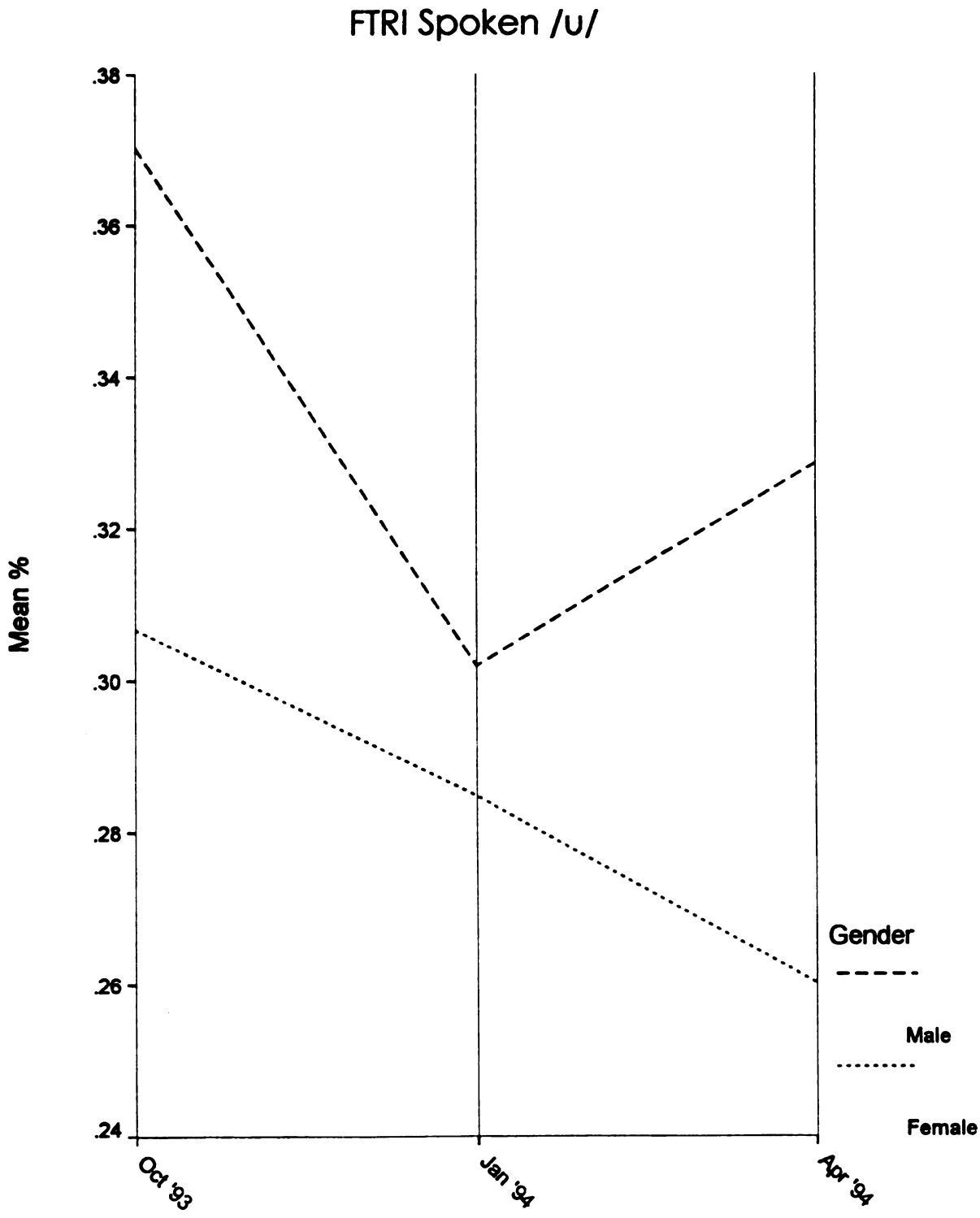

FTRI Spoken /u/
Mean %
.38
.36
.34
.32
.30
.28
.26
.24
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 92

APPENDIX AA.2

ATRI SPOKEN /u/

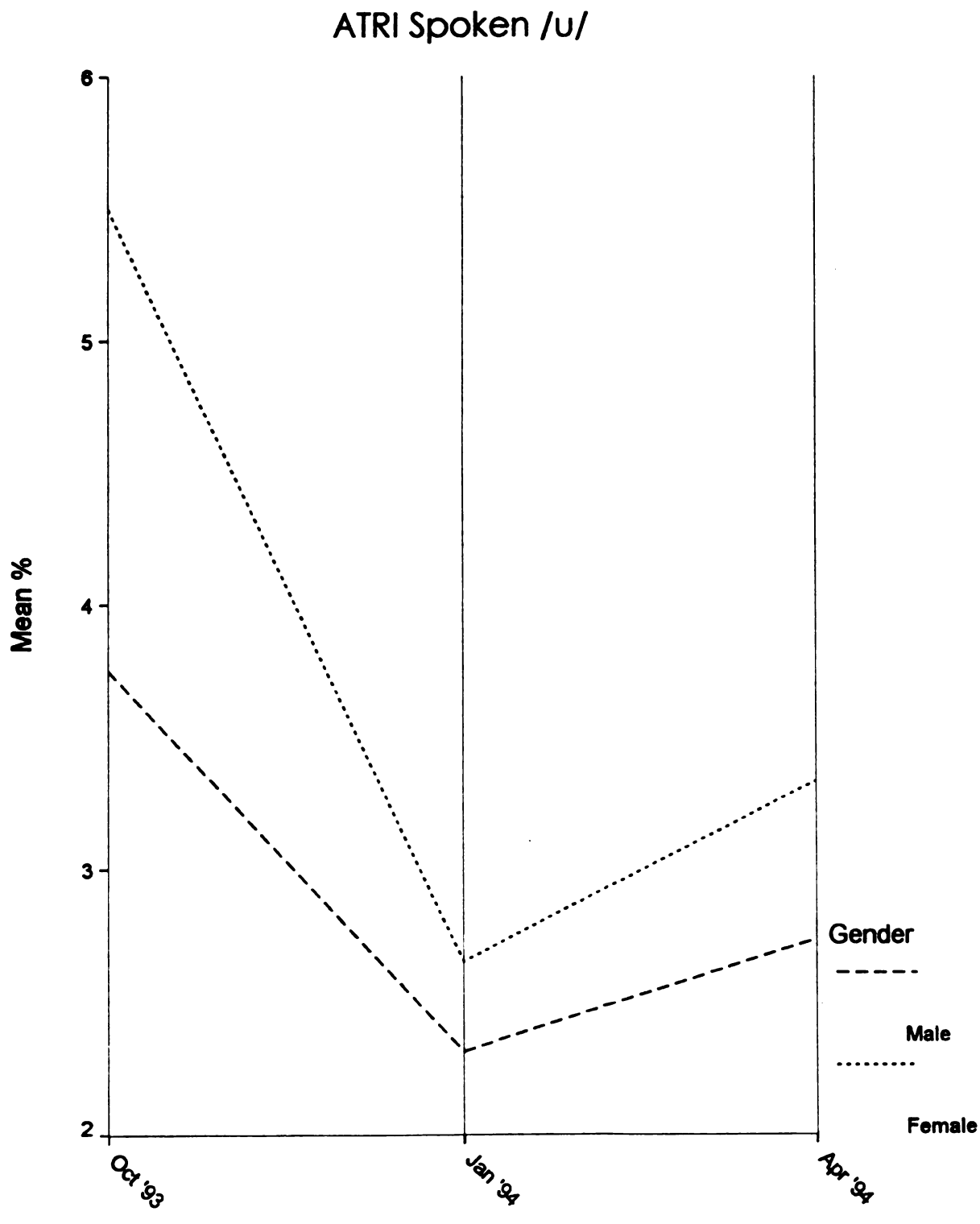

ATRI Spoken /u/
Mean %
6
5
4
3
2
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 93

APPENDIX AA.3

Fftr SPOKEN /u/

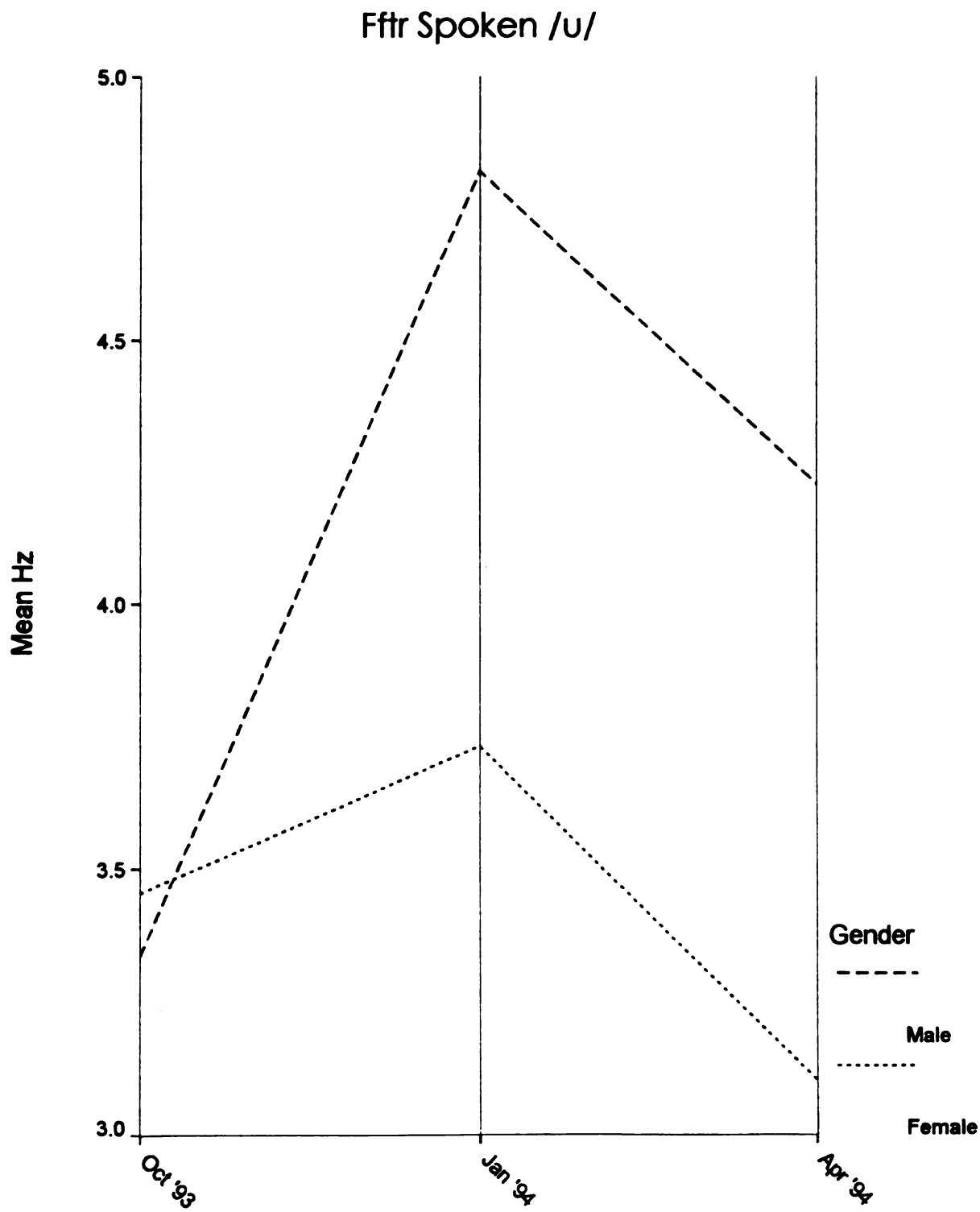

Fftr Spoken /u/
5.0
4.5
4.0
3.5
3.0
Mean Hz
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 94

APPENDIX AA.4

Fatr SPOKEN /u/

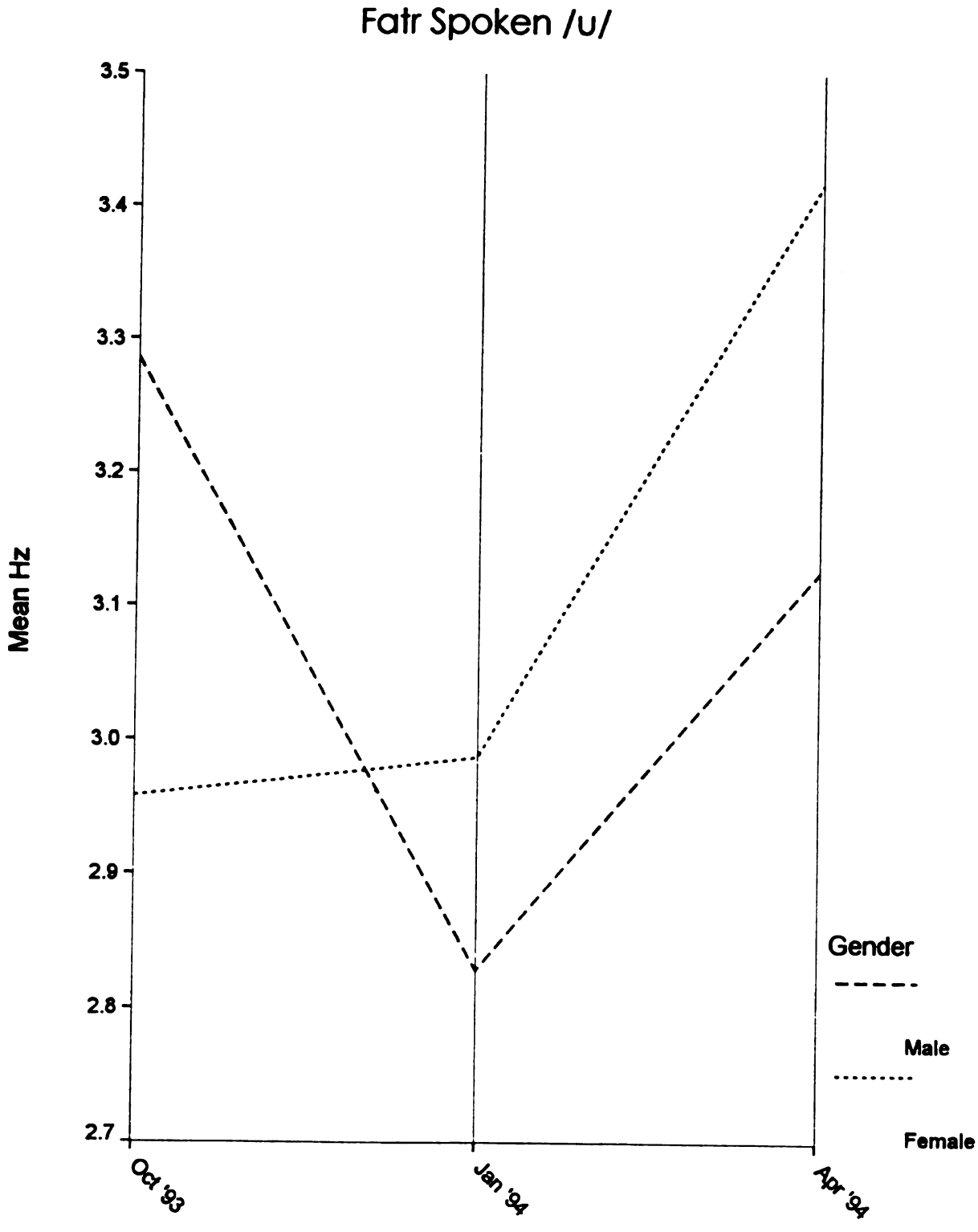

Fatr Spoken /u/
3.5
3.4
3.3
3.2
3.1
3.0
2.9
2.8
2.7
Mean Hz
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 95

APPENDIX BB.1

Fo SUNG /u/

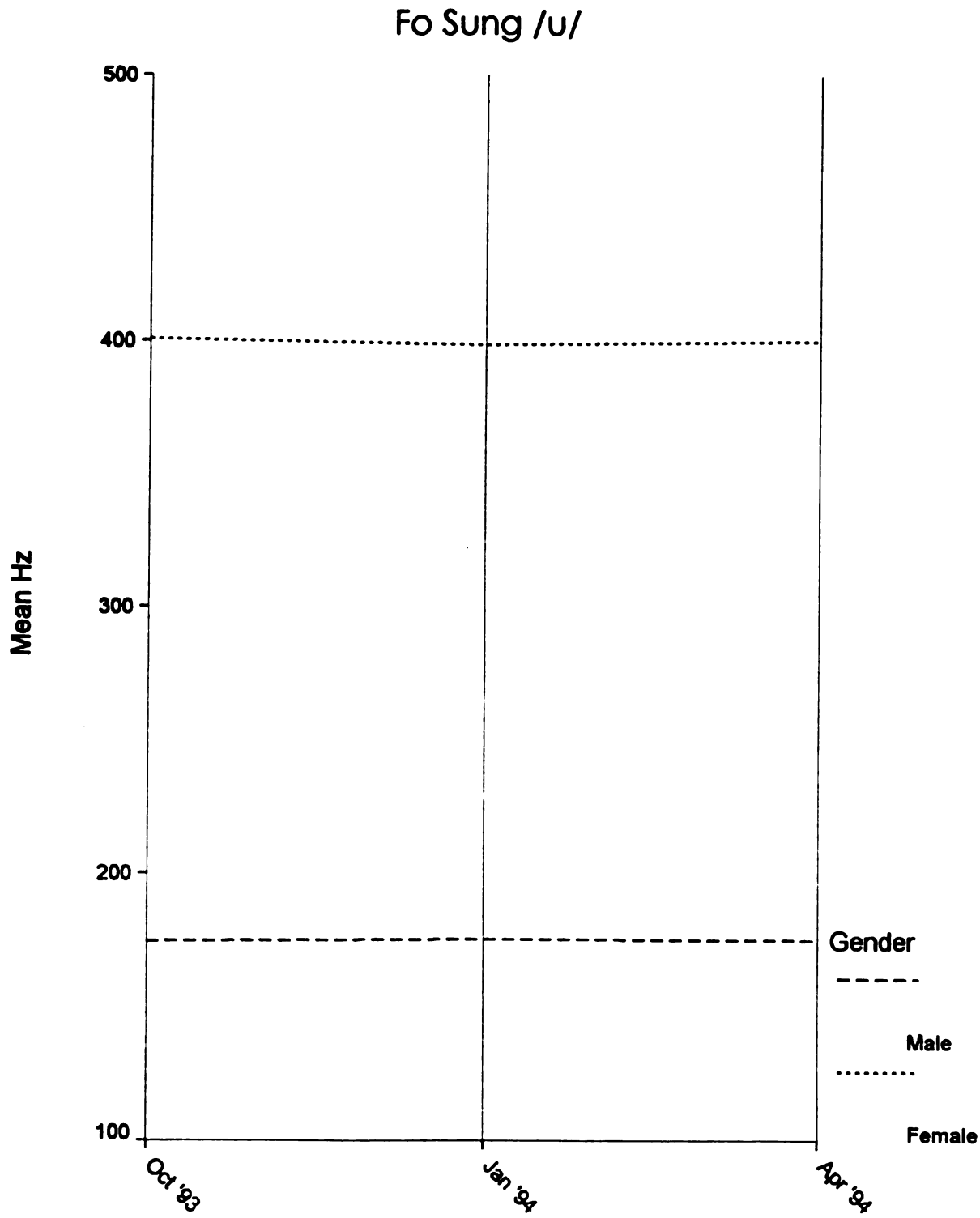

Fo Sung /u/
500
400
300
200
100
Mean Hz
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 96

APPENDIX BB.2

Jita SUNG /u/

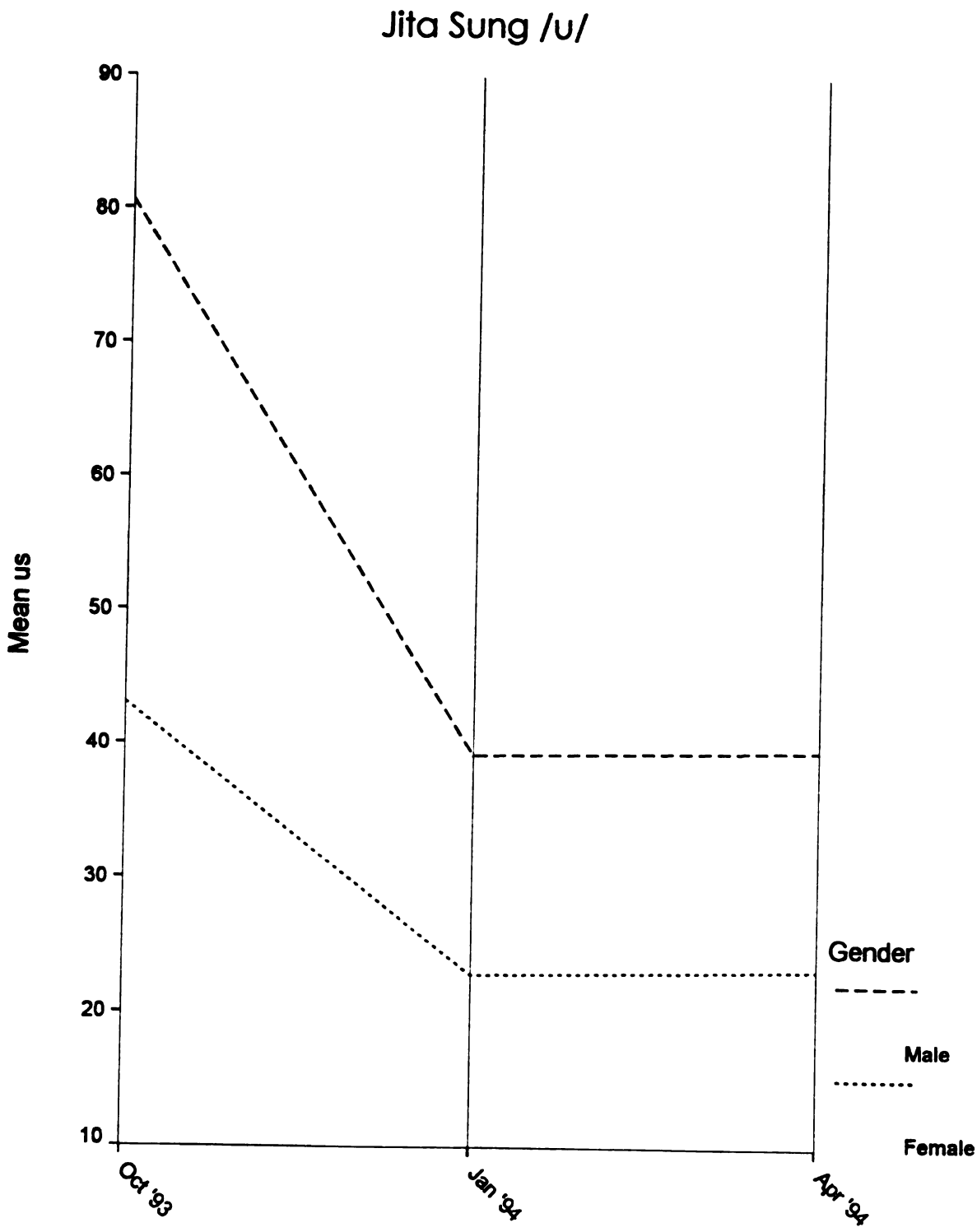

Jita Sung /u/
Mean us
90
80
70
60
50
40
30
20
10
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 97

APPENDIX BB.3

Jitt SUNG /u/

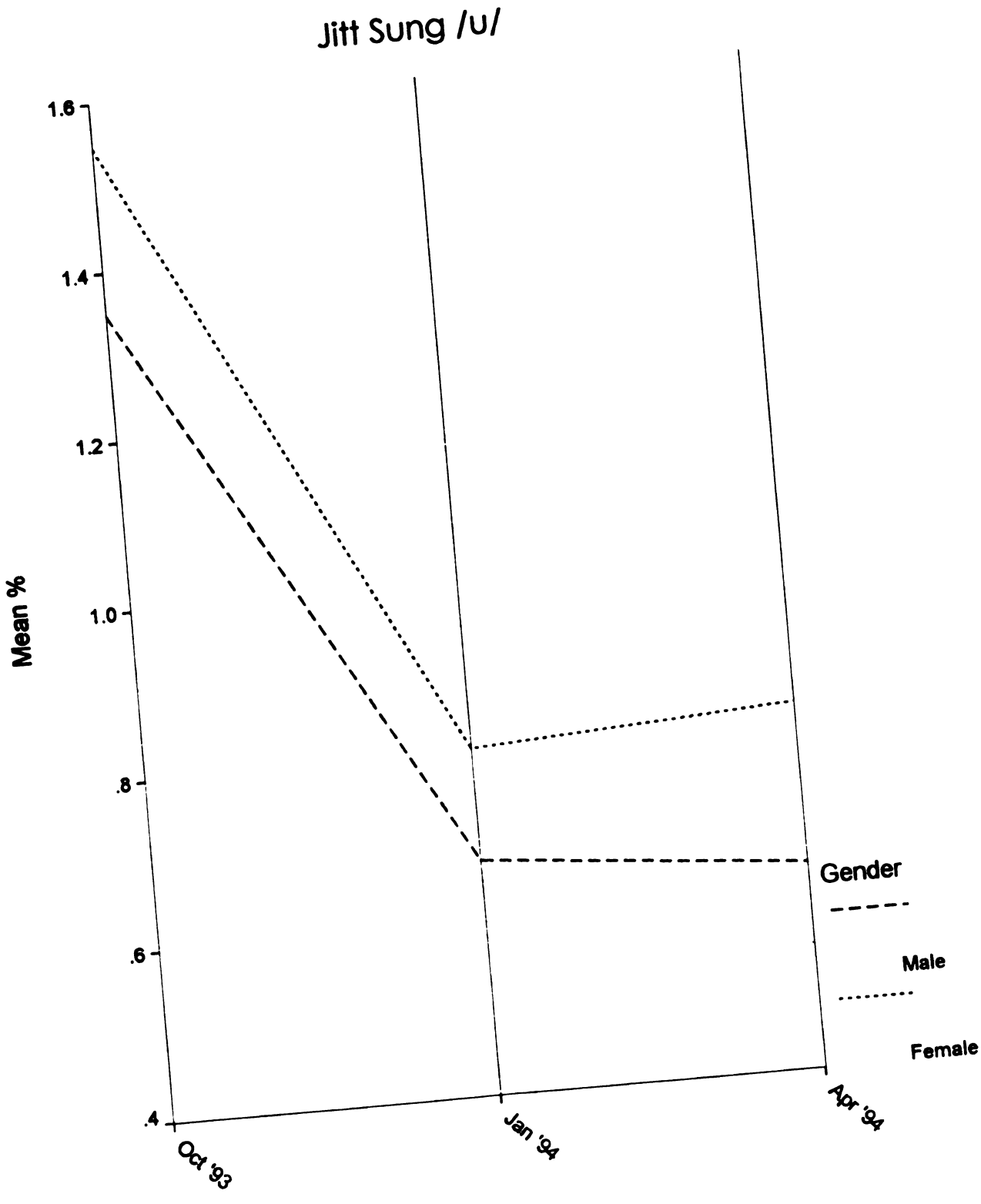

Jitt Sung /u/
1.6
1.4
1.2
1.0
.8
.6
.4
Mean %
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 98

APPENDIX BB.4

RAP SUNG /u/

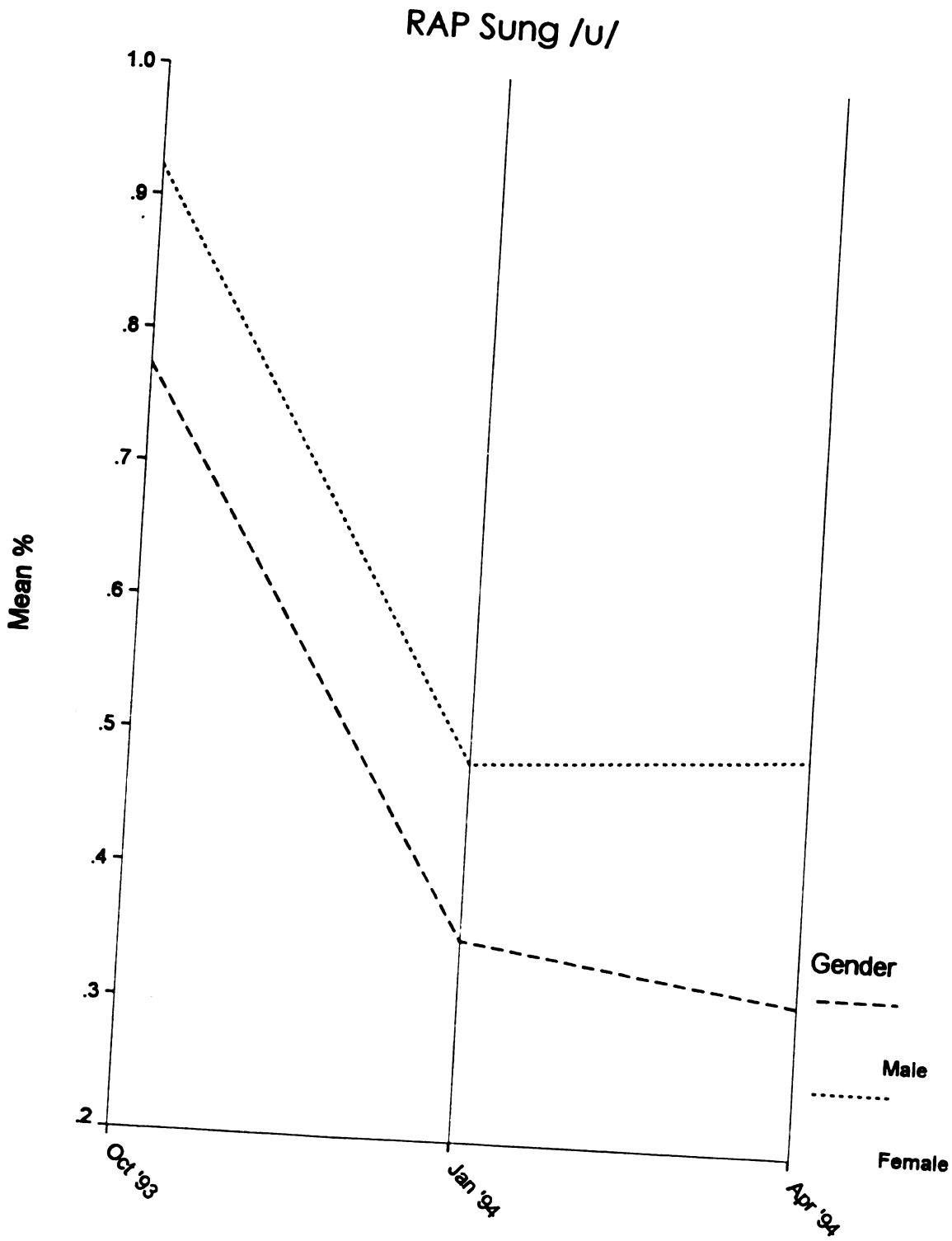

RAP Sung /u/
1.0
.9
.8
.7
.6
.5
.4
.3
.2
Mean %
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 99

APPENDIX BB.5

PPQ SUNG /u/

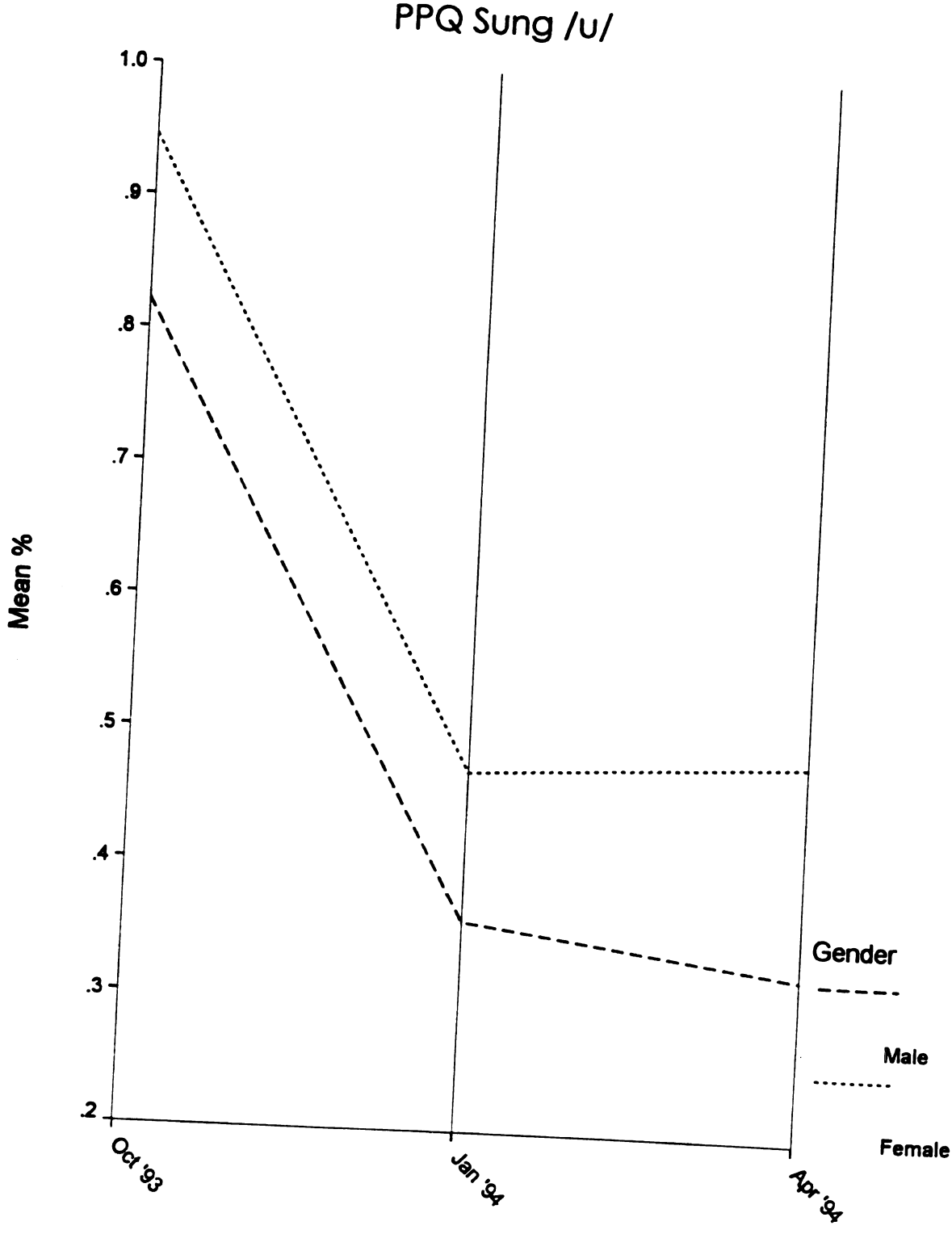

PPQ Sung /u/
1.0
.9
.8
.7
.6
.5
.4
.3
.2
Mean %
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 100

APPENDIX BB.6

sPPQ_SUNG /u/

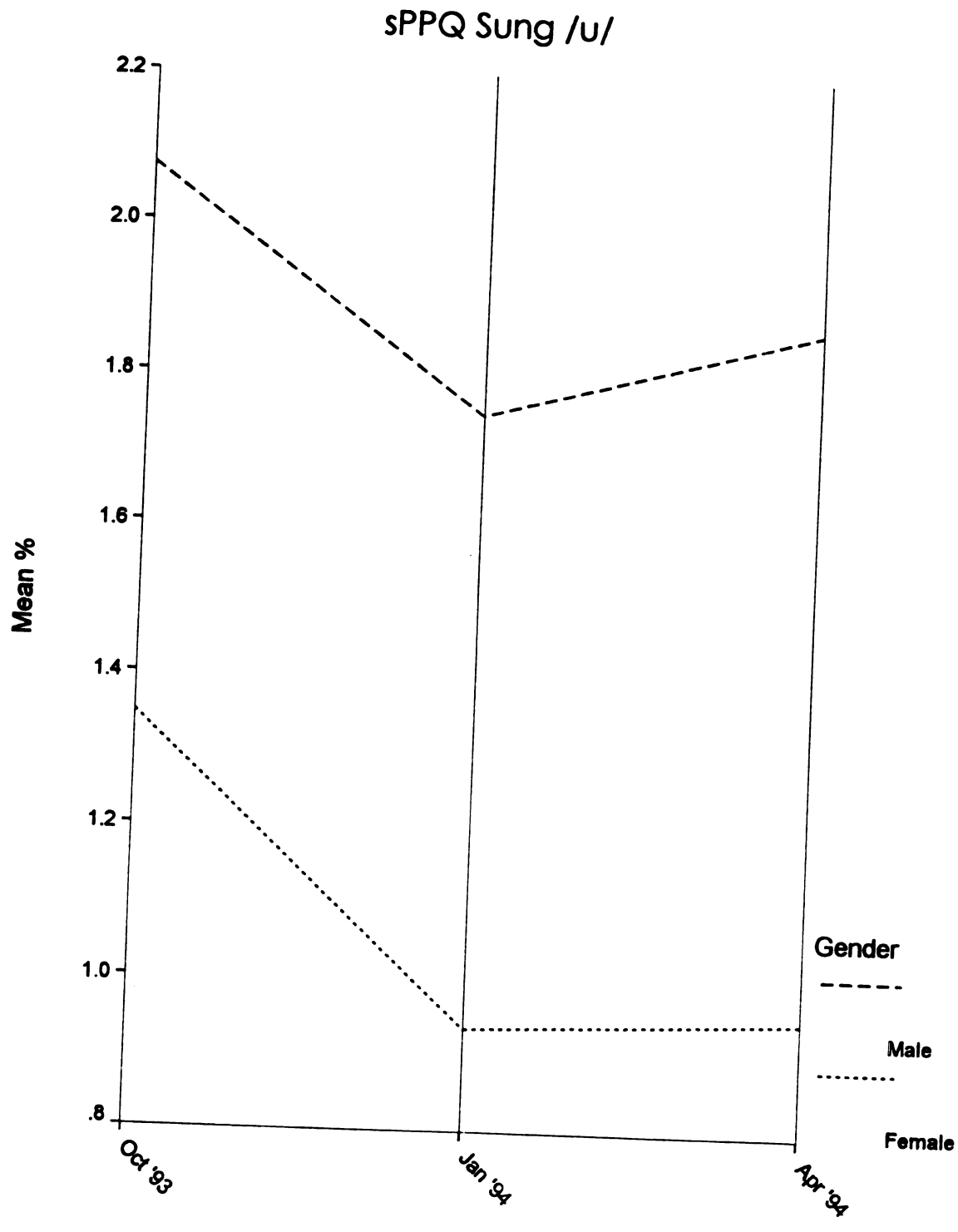

sPPQ Sung /u/
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
Mean %
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 101

APPENDIX BB.7

vFo SUNG /u/

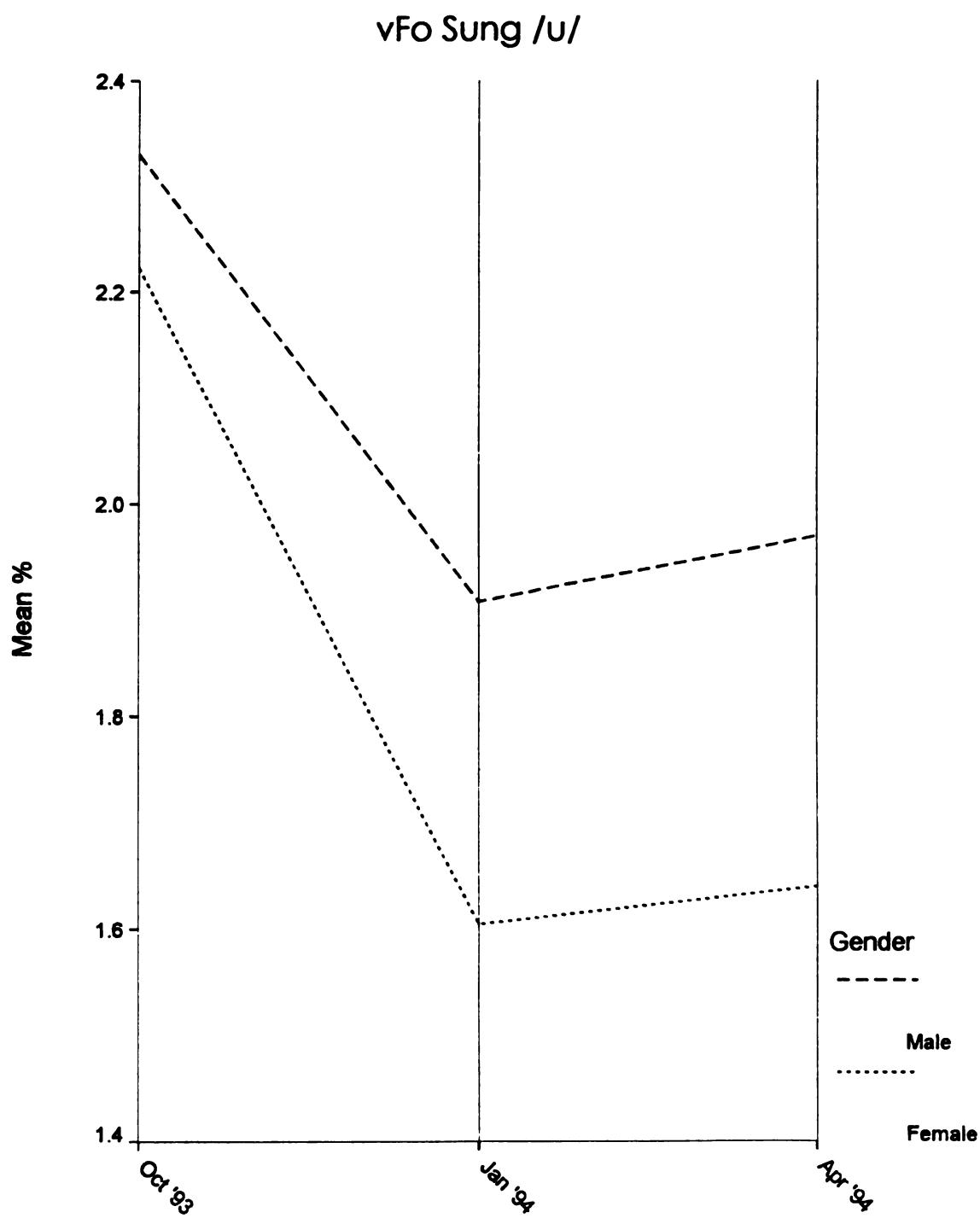

vFo Sung /u/
Mean %
2.4
2.2
2.0
1.8
1.6
1.4
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 102

APPENDIX CC.1

ShdB SUNG /u/

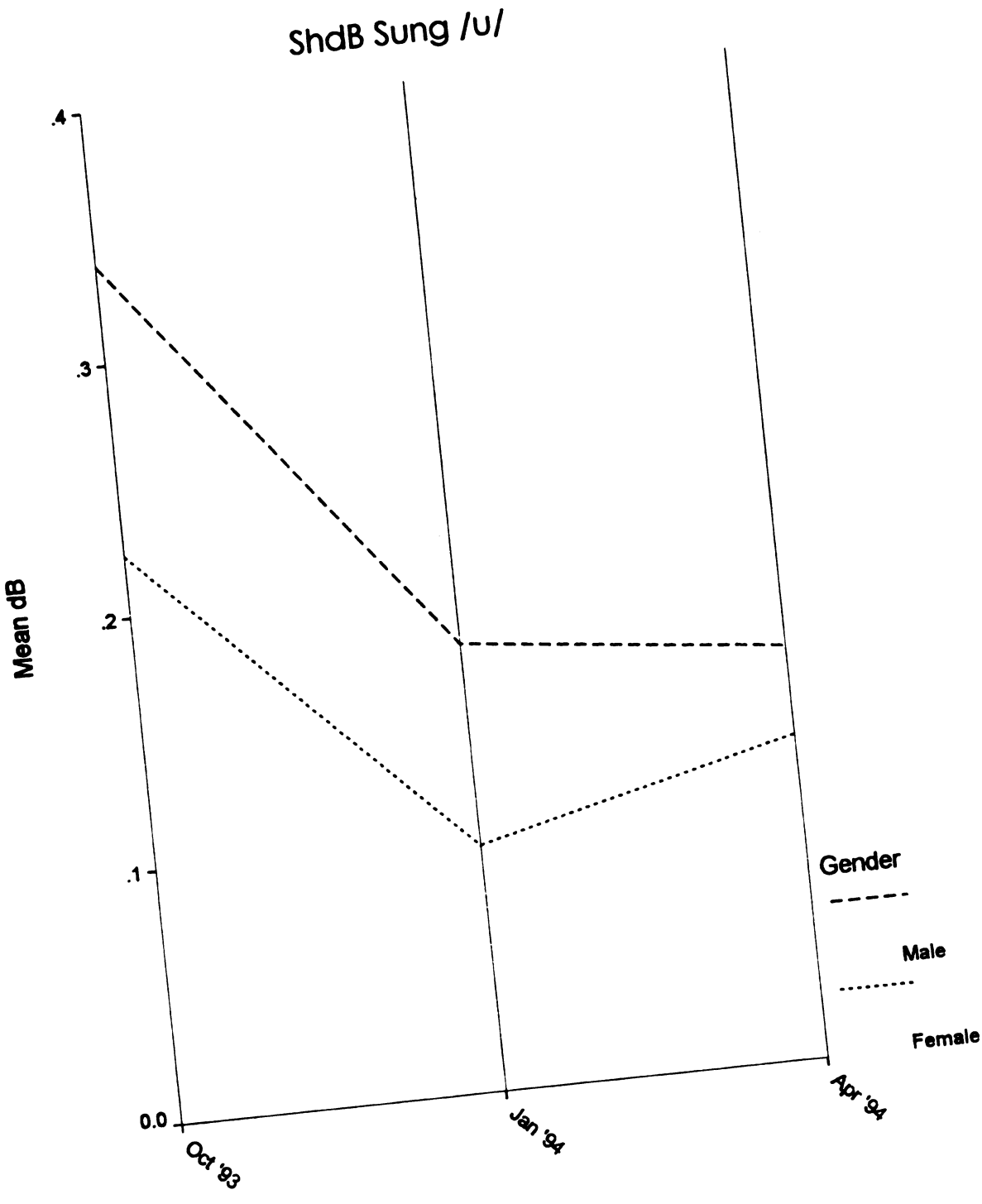

ShdB Sung /u/
Mean dB
.4
.3
.2
.1
0.0
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 103

APPENDIX CC.2

Shim SUNG /u/

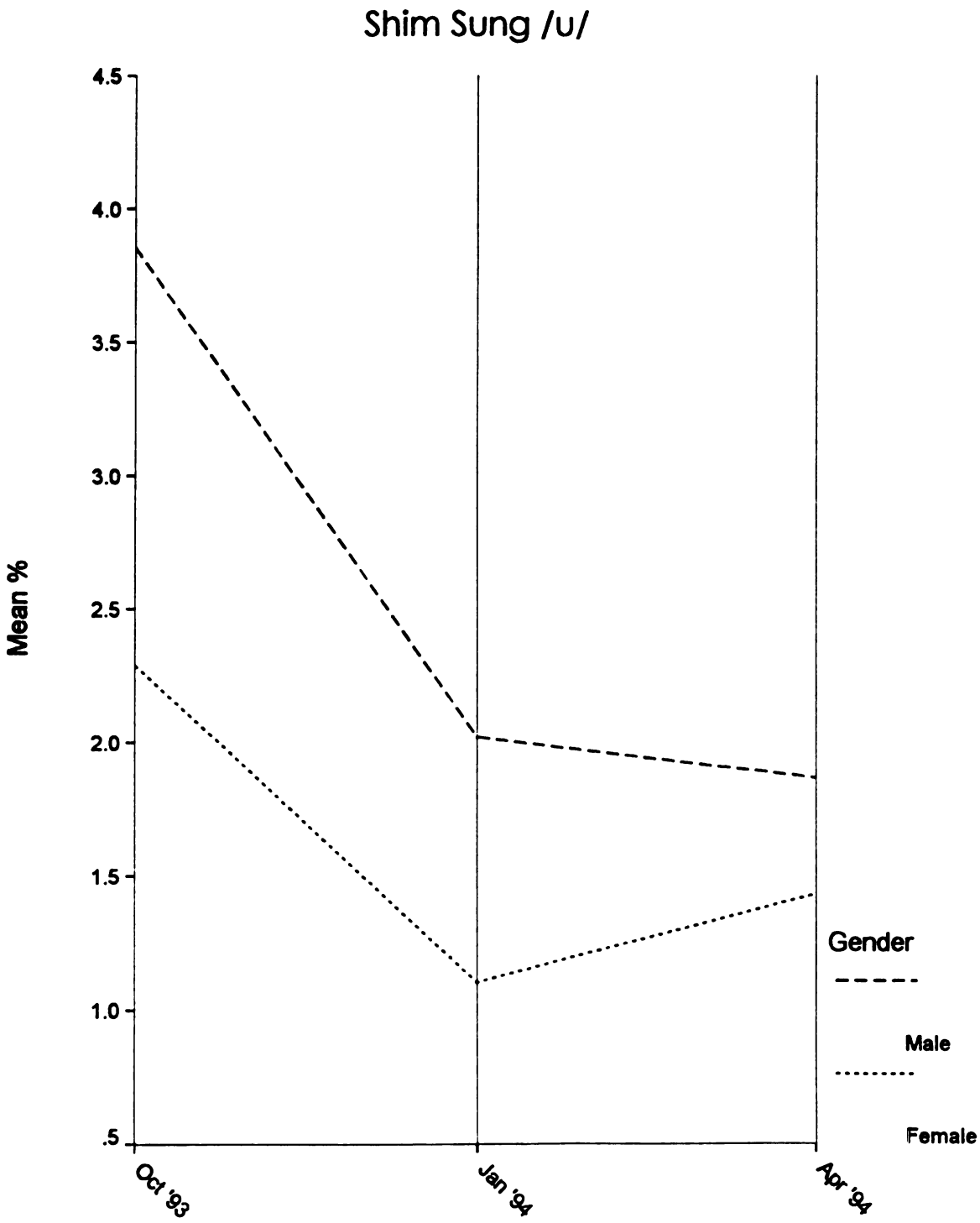

Shim Sung /u/
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
.5
Mean %
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 104

APPENDIX CC.3

APQ SUNG /u/

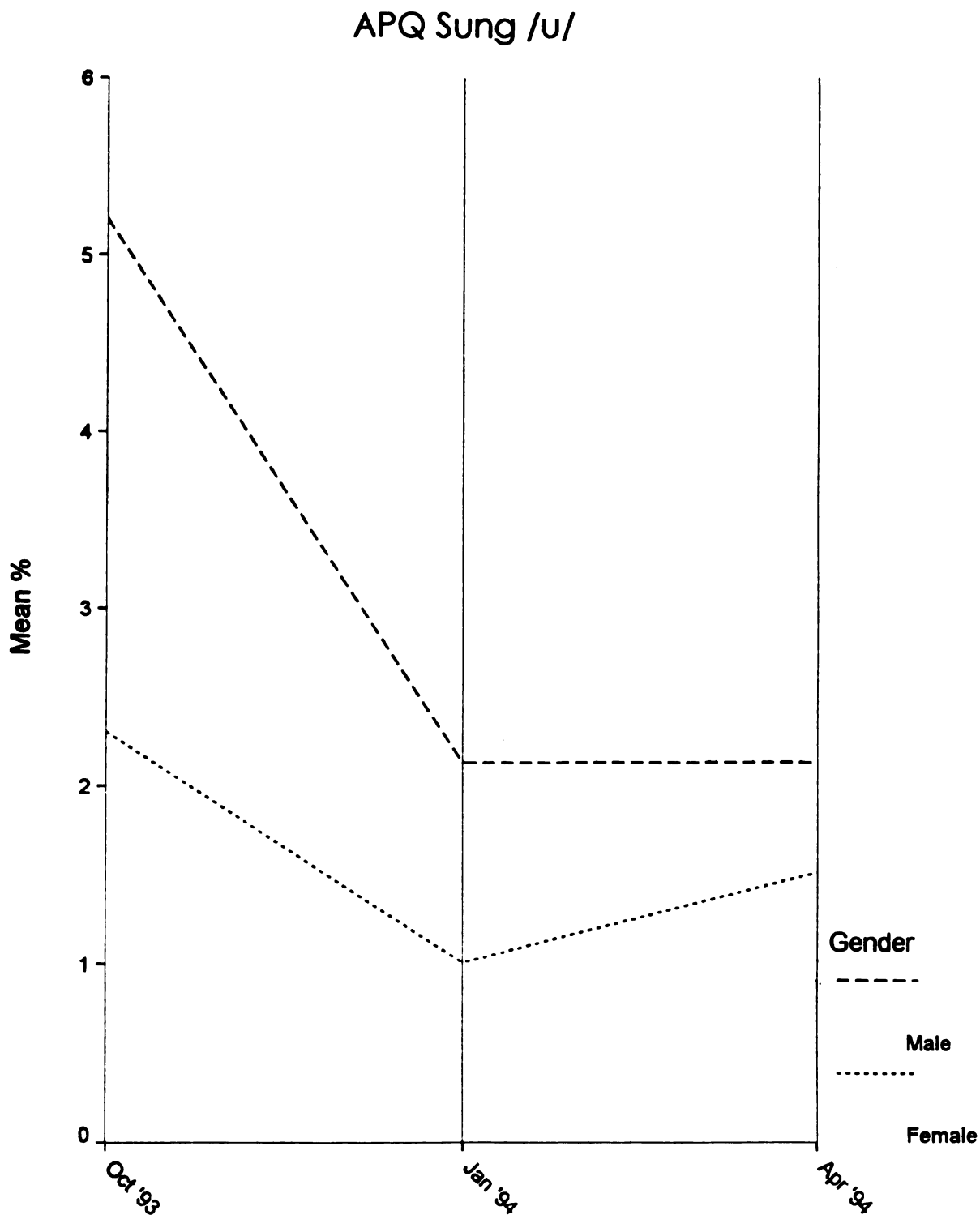

APQ Sung /u/
Mean %
6
5
4
3
2
1
0
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 105

APPENDIX CC.4

sAPQ SUNG /u/

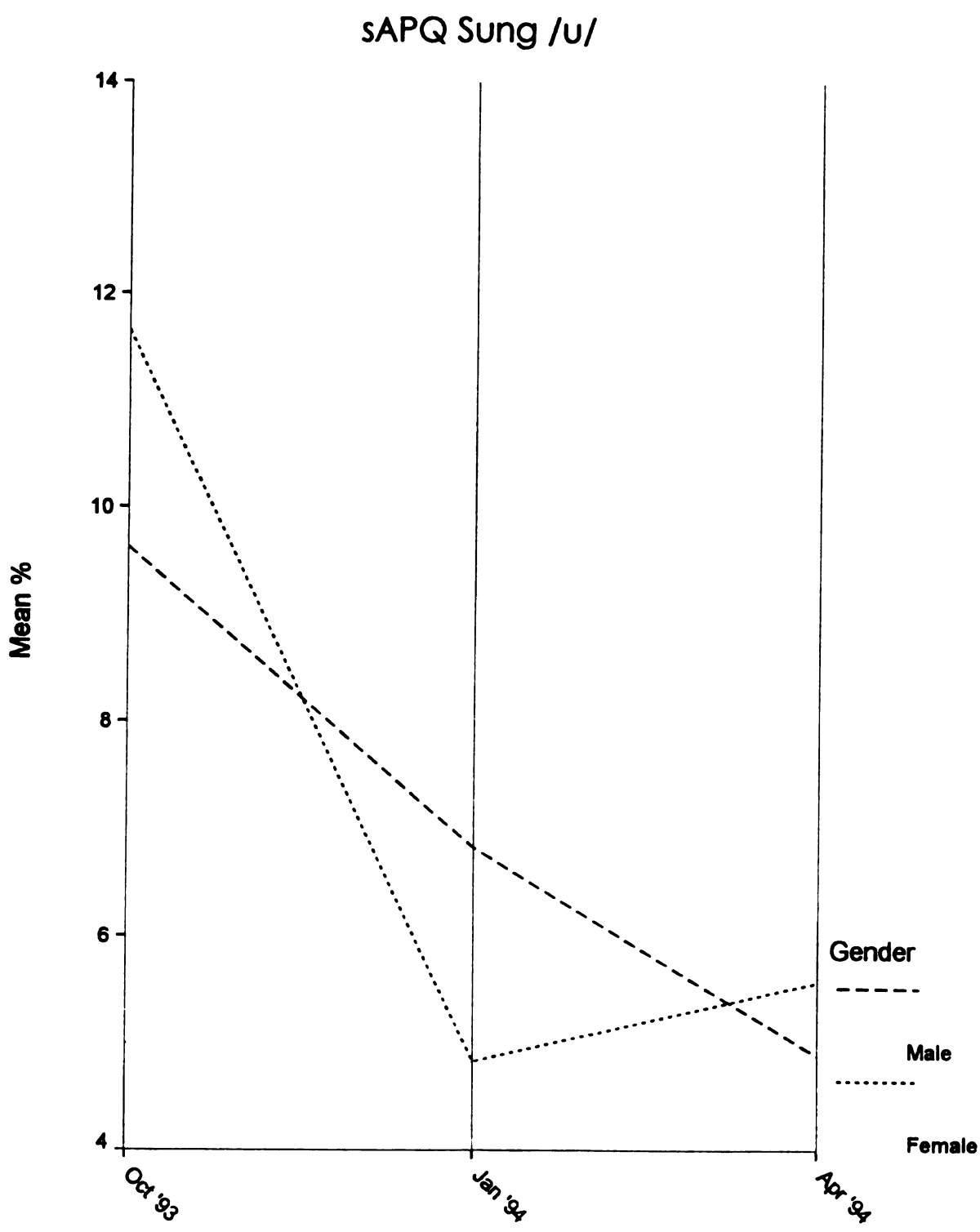

sAPQ Sung /u/
14
12
10
8
6
4
Mean %
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 106

APPENDIX CC.5

vAm SUNG /u/

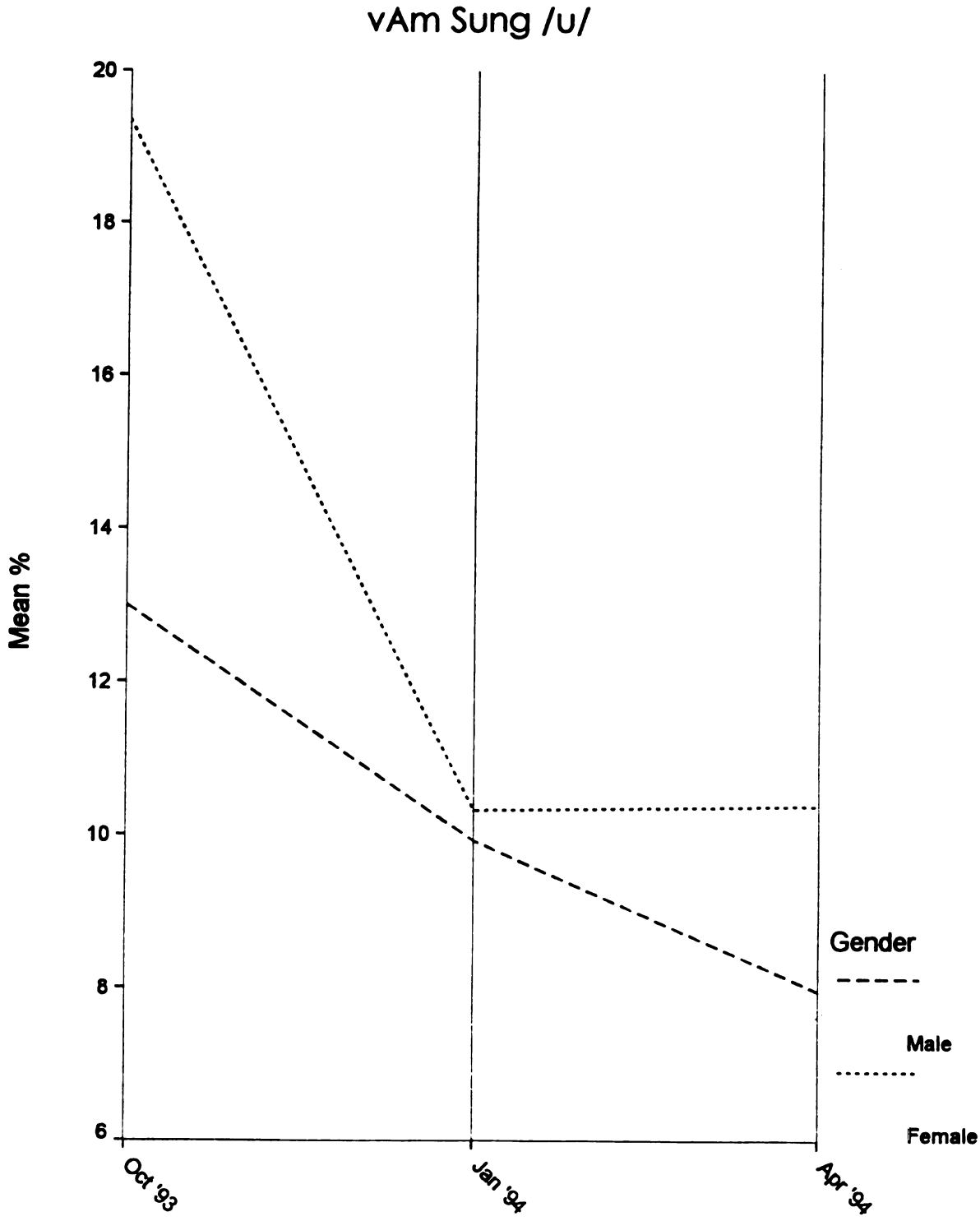

vAm Sung /u/
20
18
16
14
12
10
8
6
Mean %
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 107

APPENDIX DD.1

NHR SUNG /u/

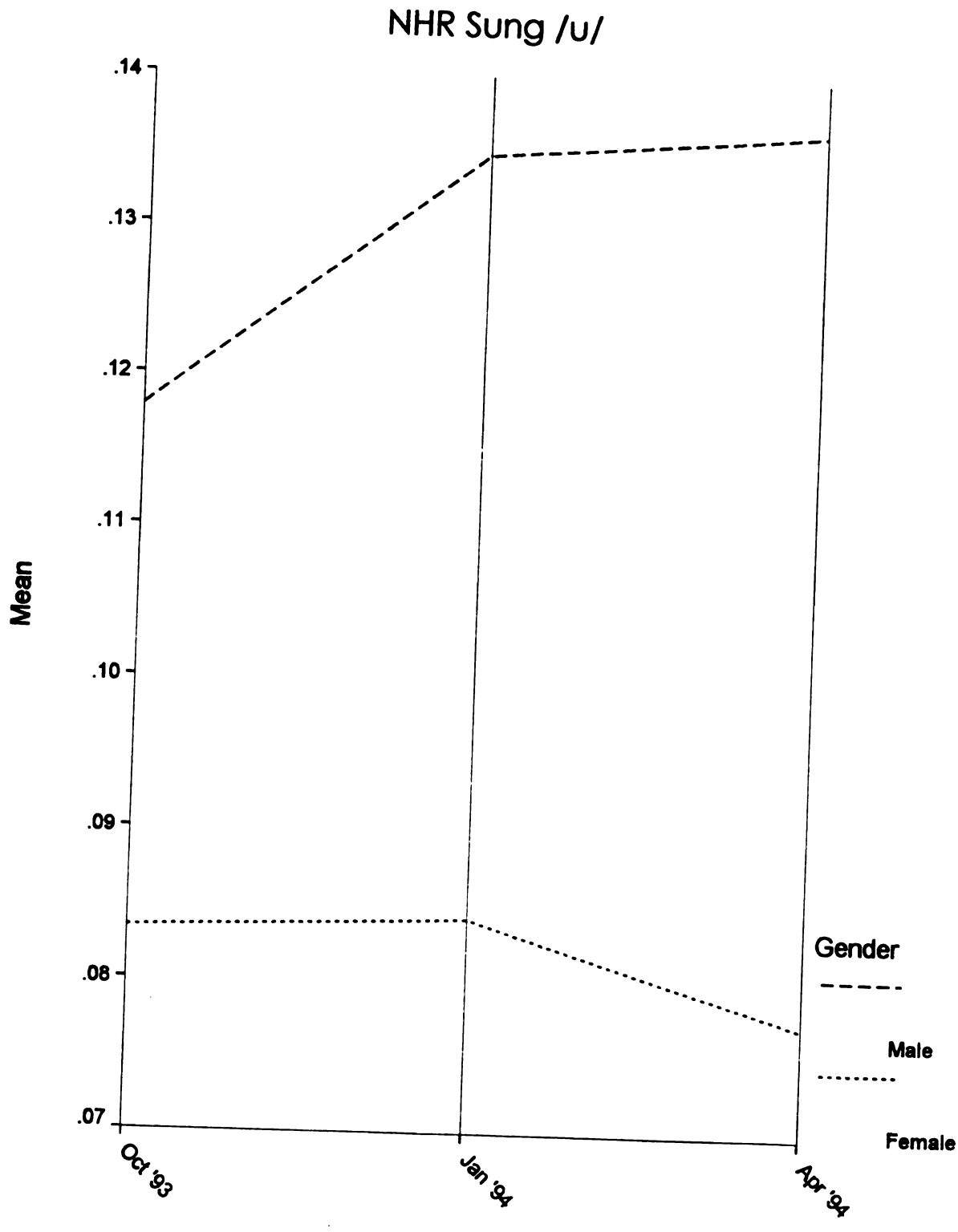

NHR Sung /u/
.14
.13
.12
.11
.10
.09
.08
.07
Mean
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 108

APPENDIX DD.2

VTI SUNG /u/

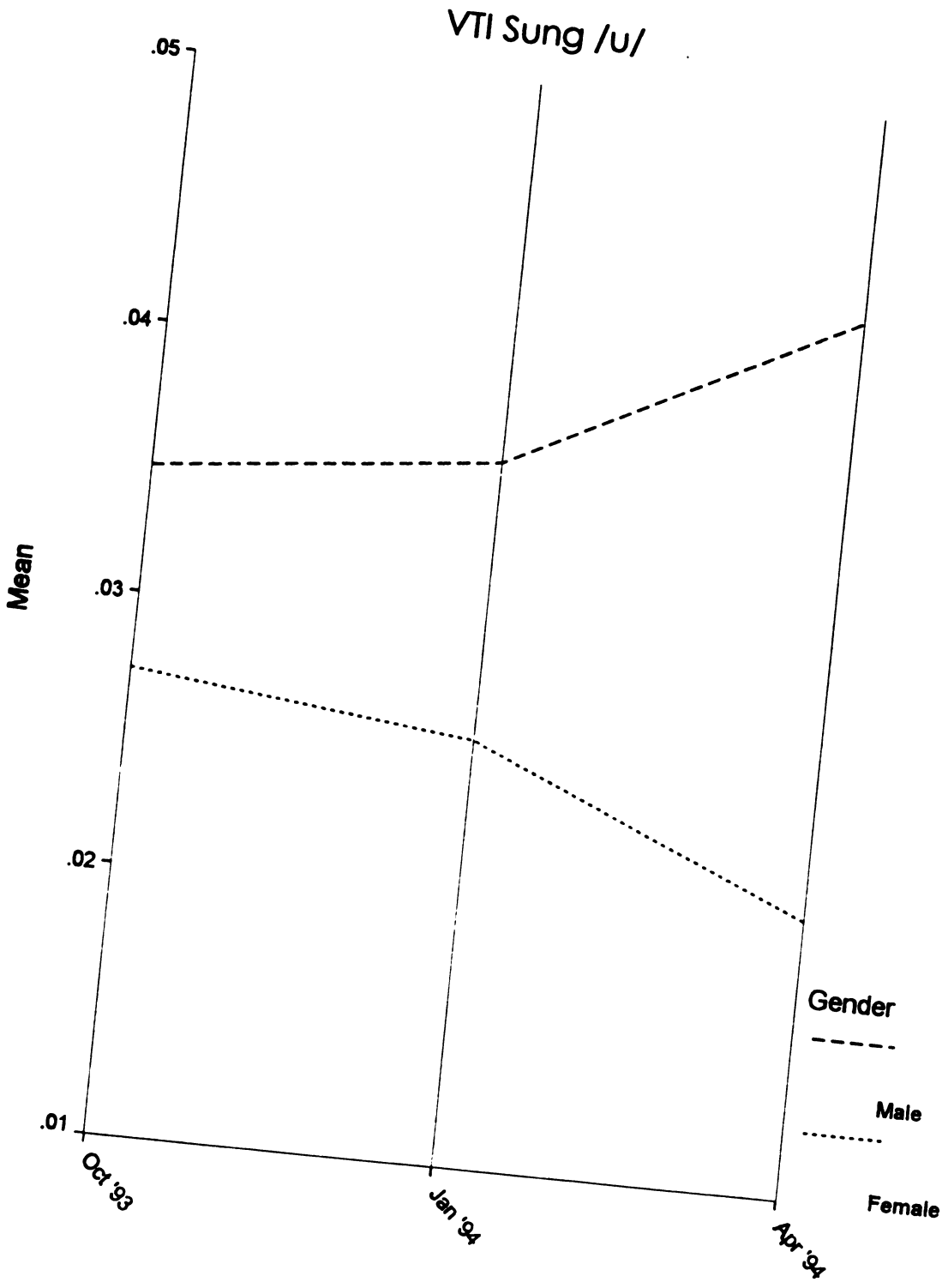

VTI Sung /u/
.05
.04
.03
.02
.01
Mean
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 109

APPENDIX DD.3

SPI SUNG /u/

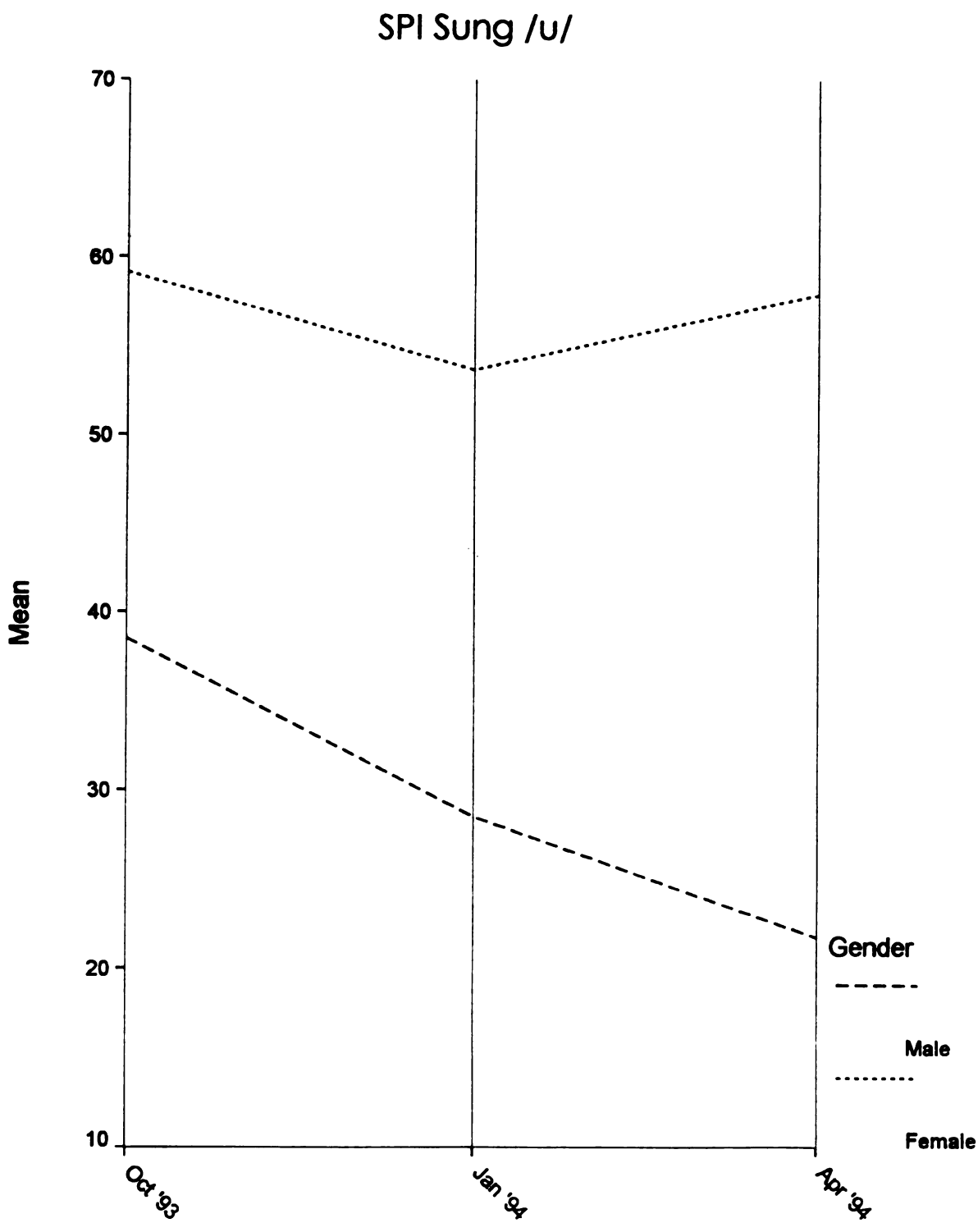

SPI Sung /u/
70
60
50
40
30
20
10
Mean
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 110

APPENDIX EE.1

FTRI SUNG /u/

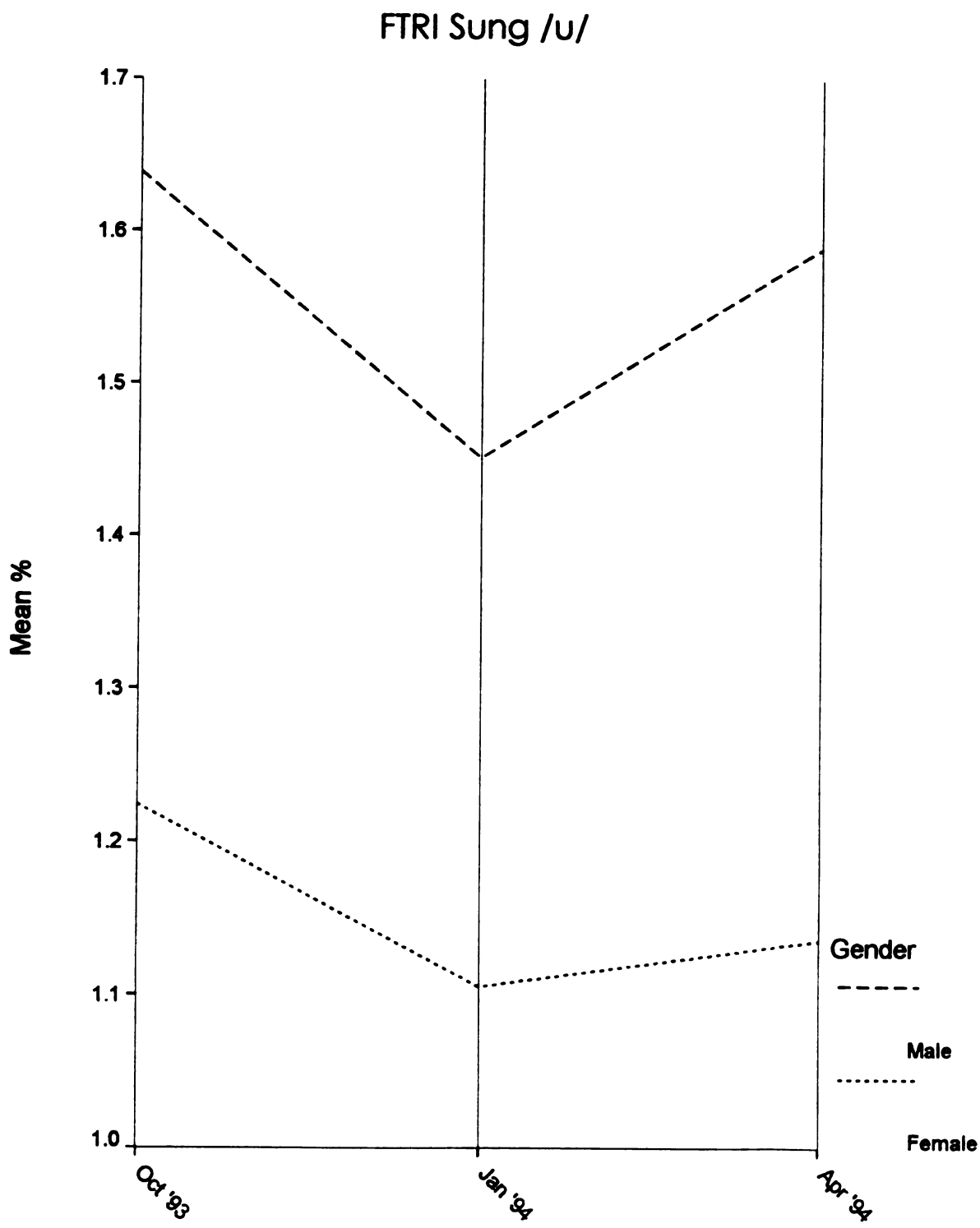

FTRI Sung /u/
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
Mean %
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 111

APPENDIX EE.2

ATRI SUNG /u/

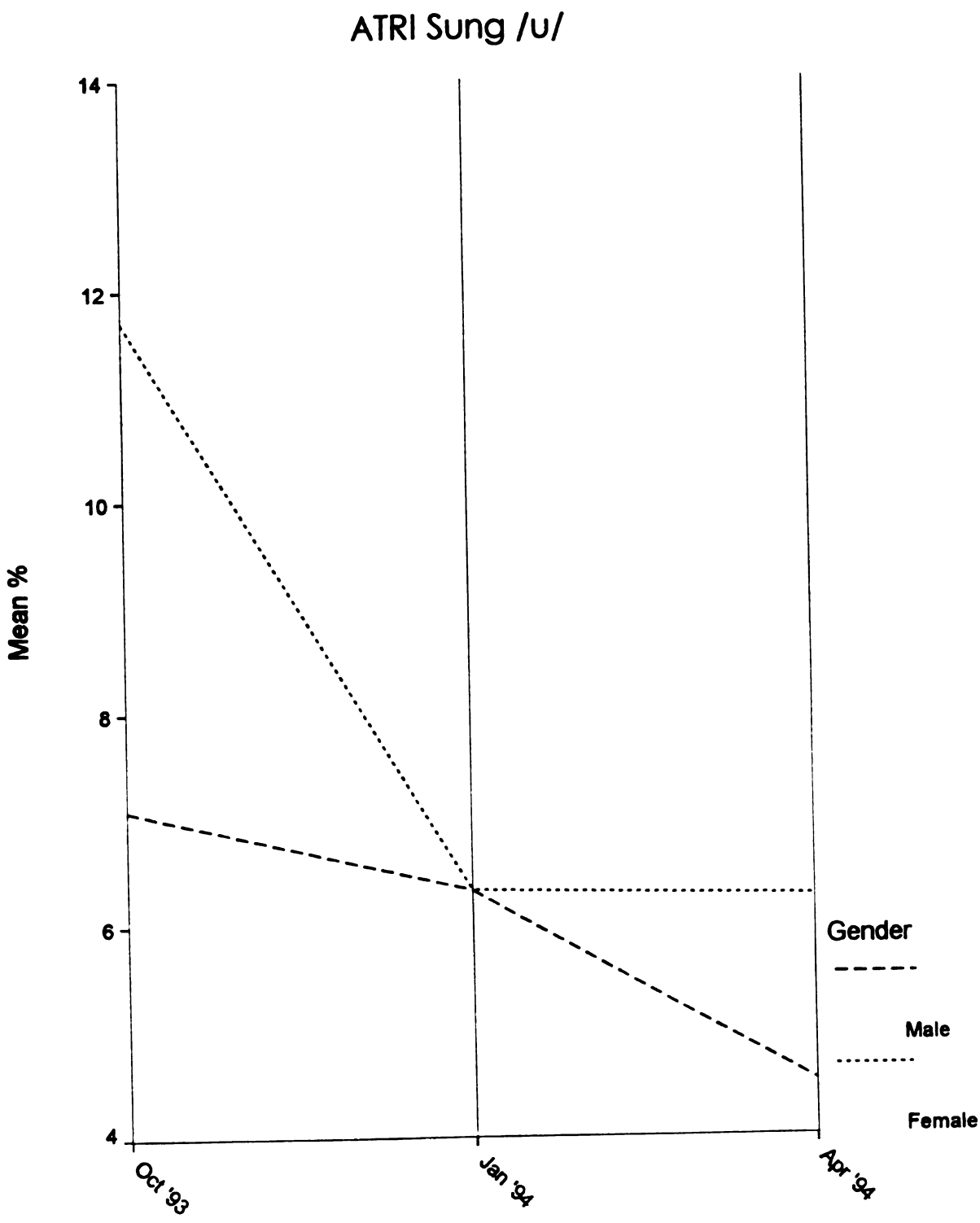

ATRI Sung /u/
14
12
10
8
6
4
Mean %
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 112

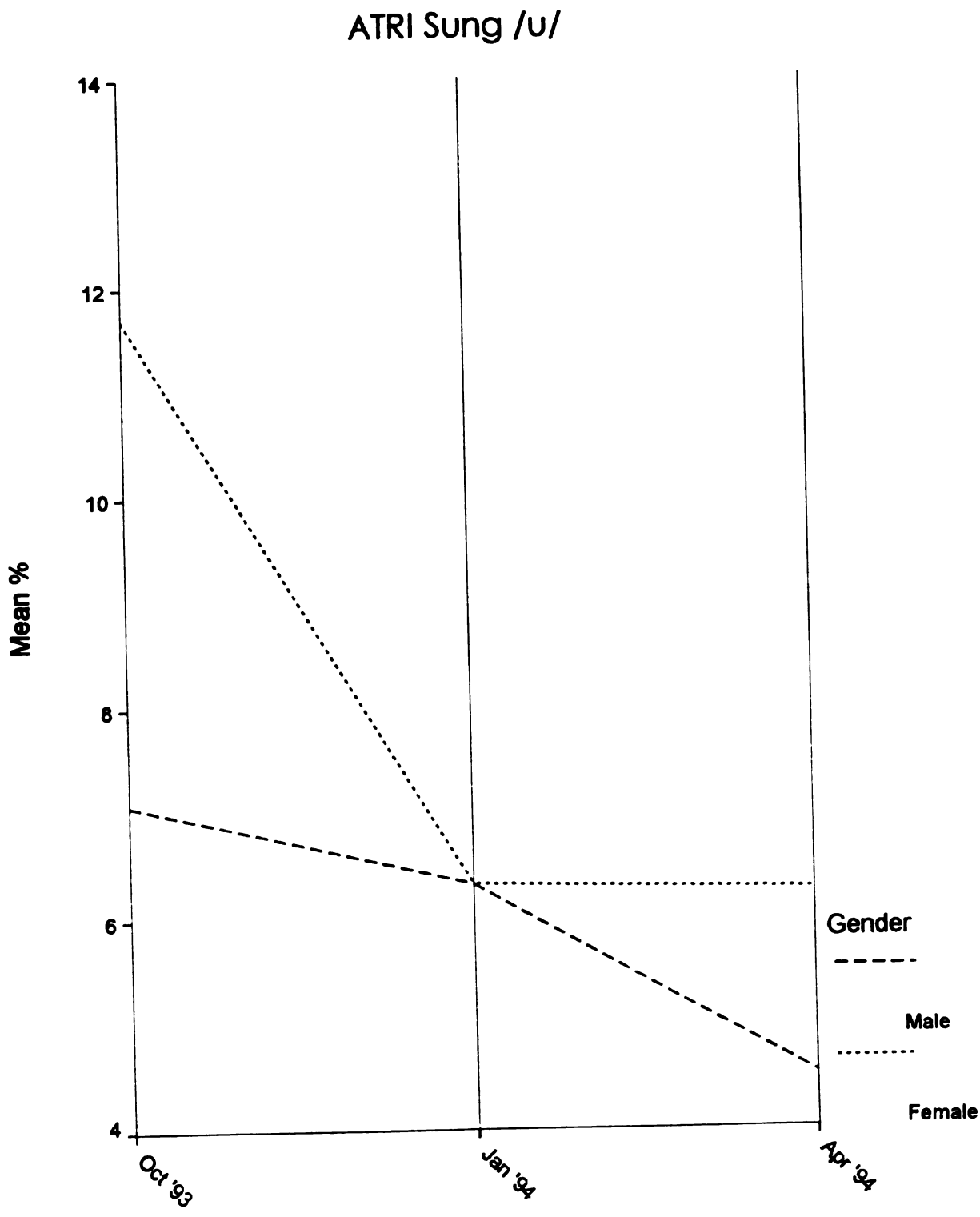

ATRI Sung /u/
14
12
10
8
6
4
Mean %
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 112

APPENDIX EE.3

Fftr SUNG /u/

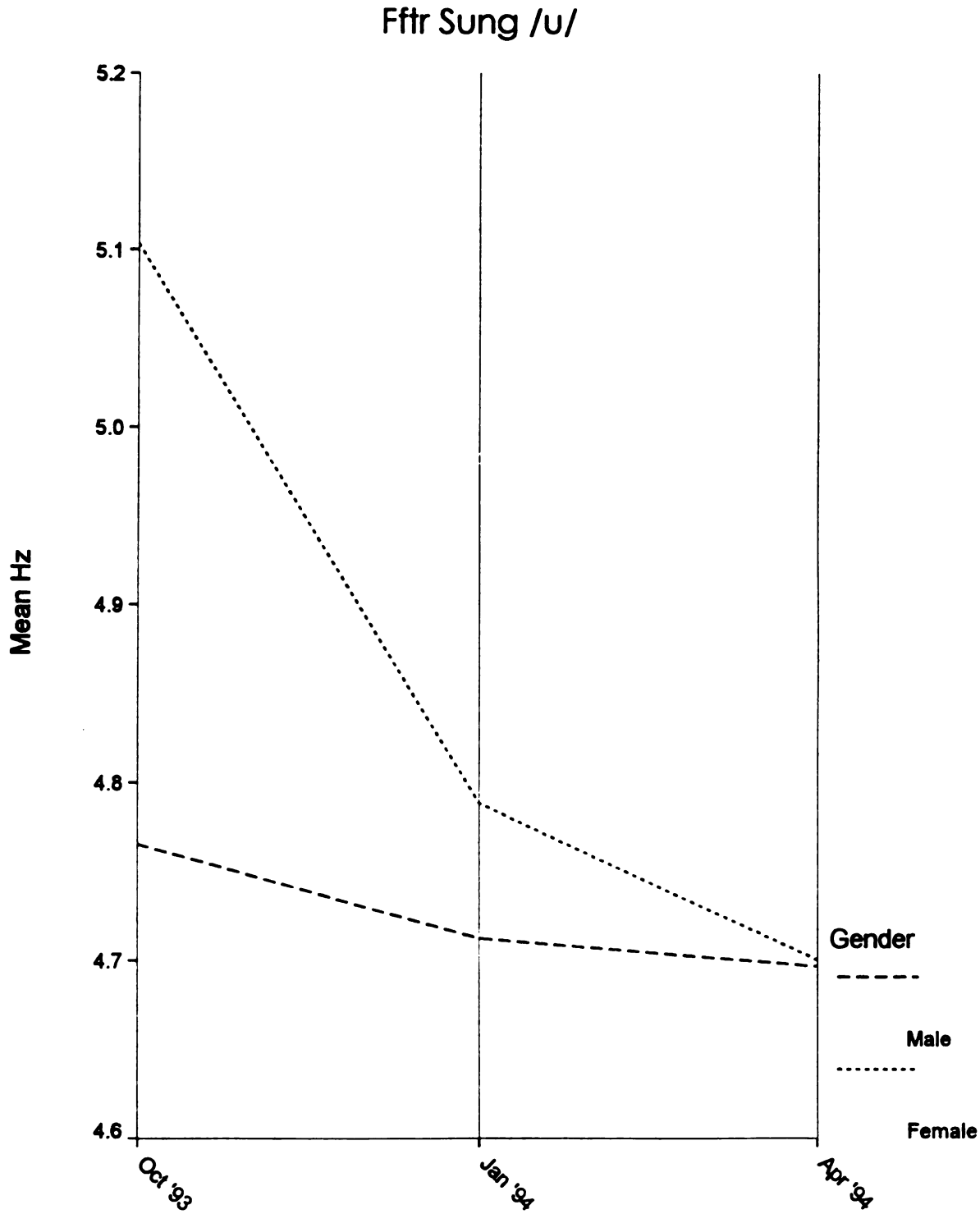

Fftr Sung /u/
Mean Hz
5.2
5.1
5.0
4.9
4.8
4.7
4.6
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 113

APPENDIX EE.4

Fatr SUNG /u/

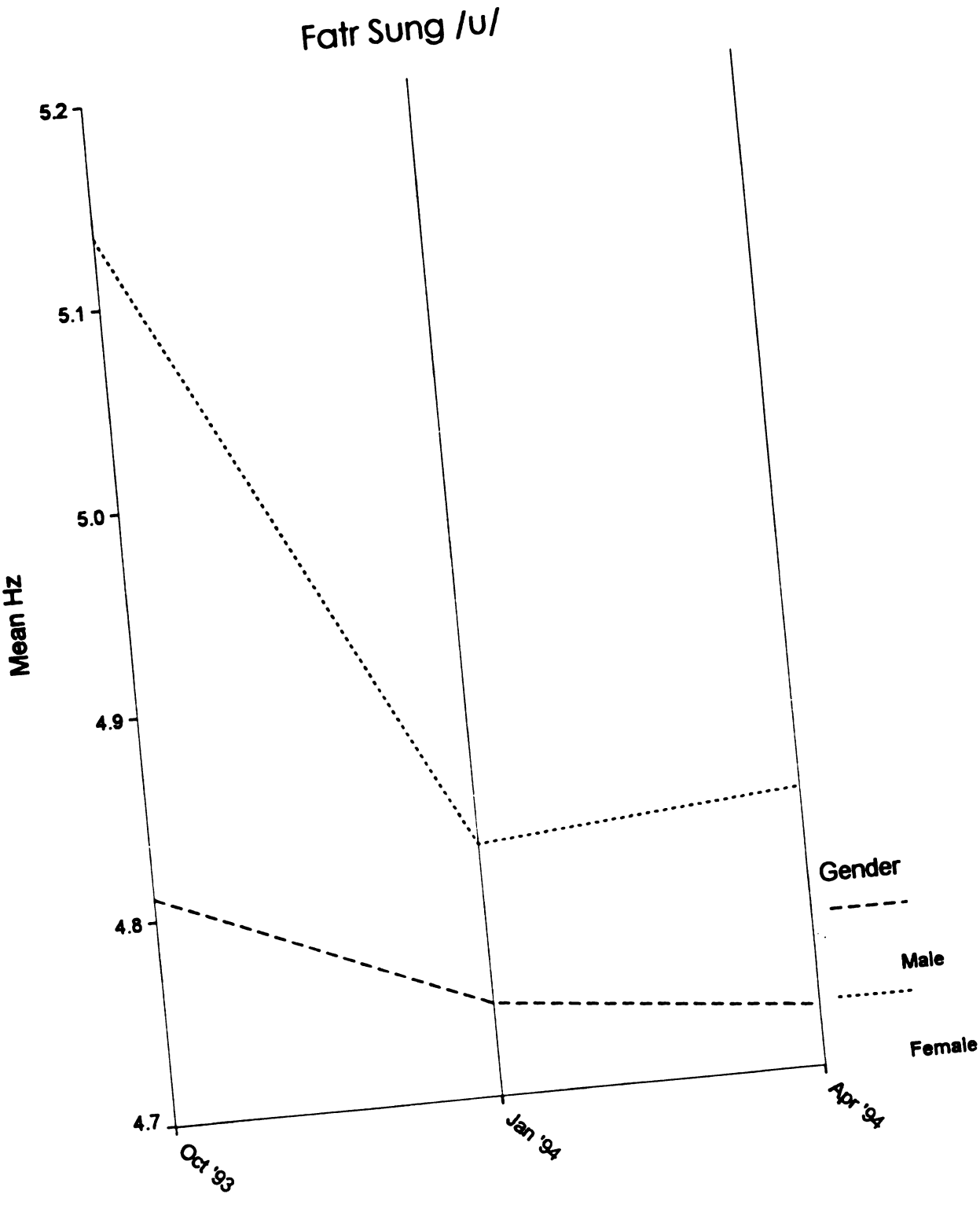

Fatr Sung /u/
5.2
5.1
5.0
4.9
4.8
4.7
Mean Hz
Oct '93
Jan '94
Apr '94
Gender
Male
Female

FIGURE 114

APPENDIX FF.1

CONVERSATIONAL Fo

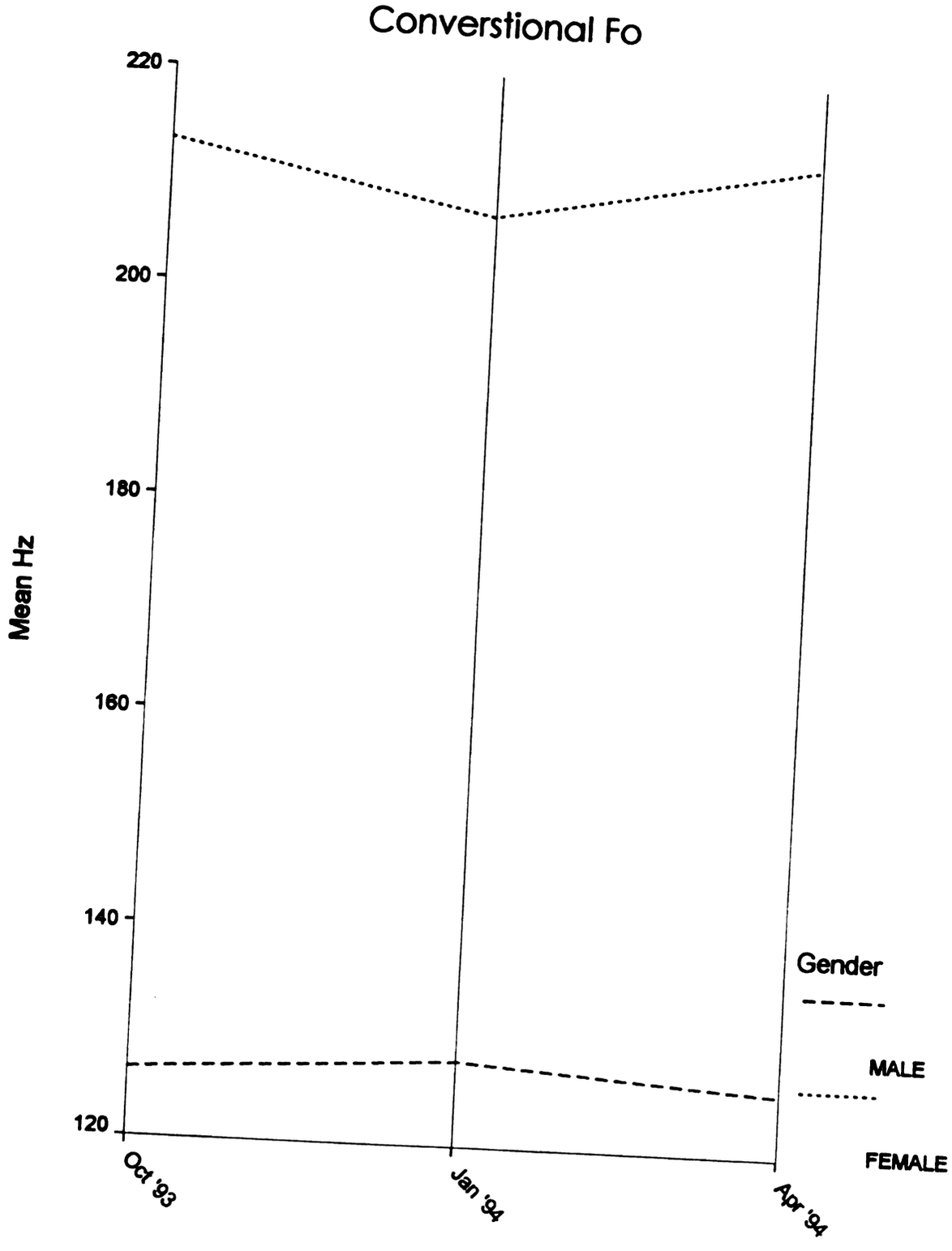

Converstional Fo
220
200
180
160
140
120
Mean Hz
Oct '93
Jan '94
Apr '94
Gender
MALE
FEMALE

FIGURE 115

APPENDIX FF.2

PHYSIOLOGICAL FREQUENCY RANGE OF PHONATION - HIGH

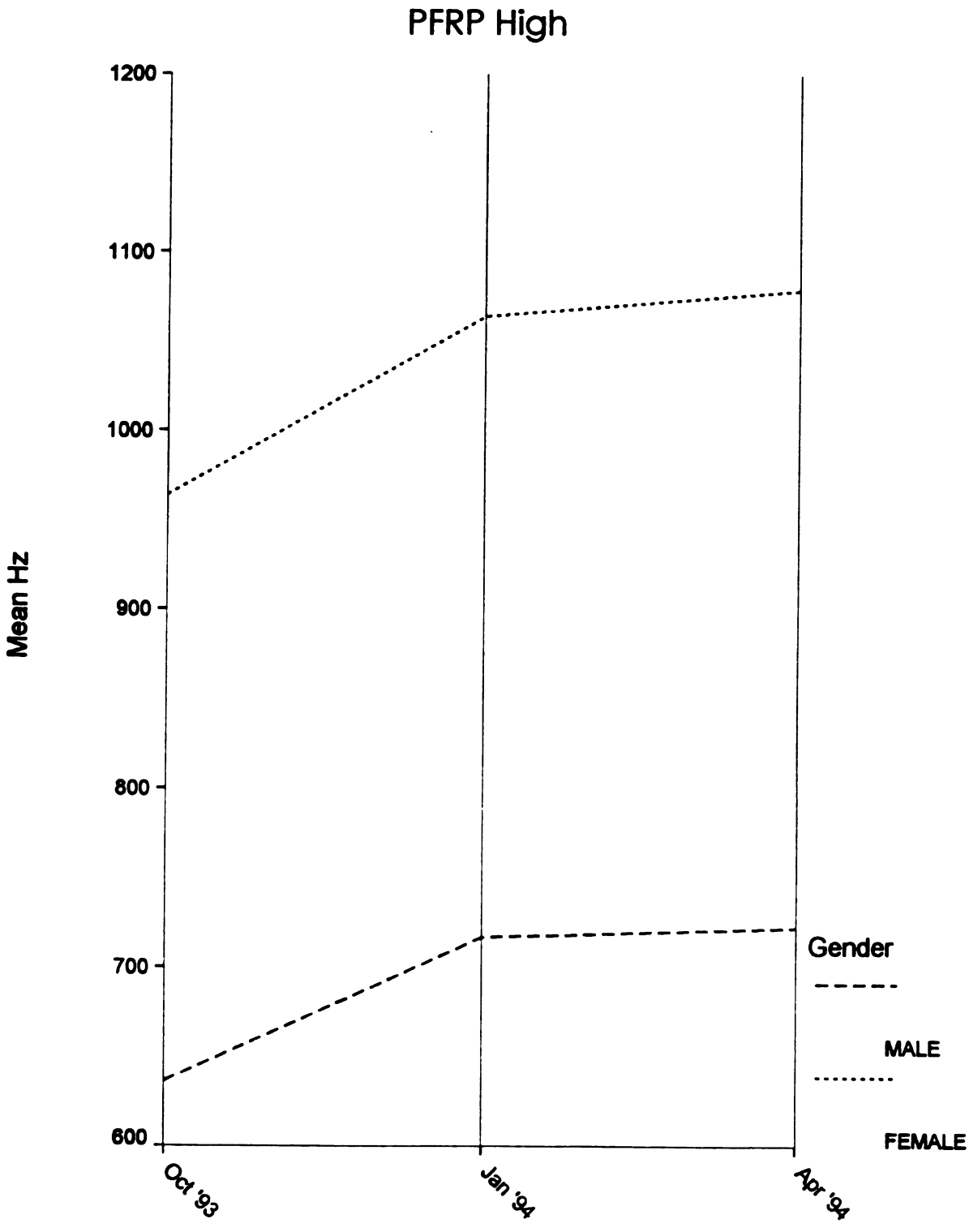

PFRP High
1200
1100
1000
900
800
700
600
Mean Hz
Oct '93
Jan '94
Apr '94
Gender
MALE
FEMALE

FIGURE 116

APPENDIX FF.3

PHYSIOLOGICAL FREQUENCY RANGE OF PHONATION - LOW

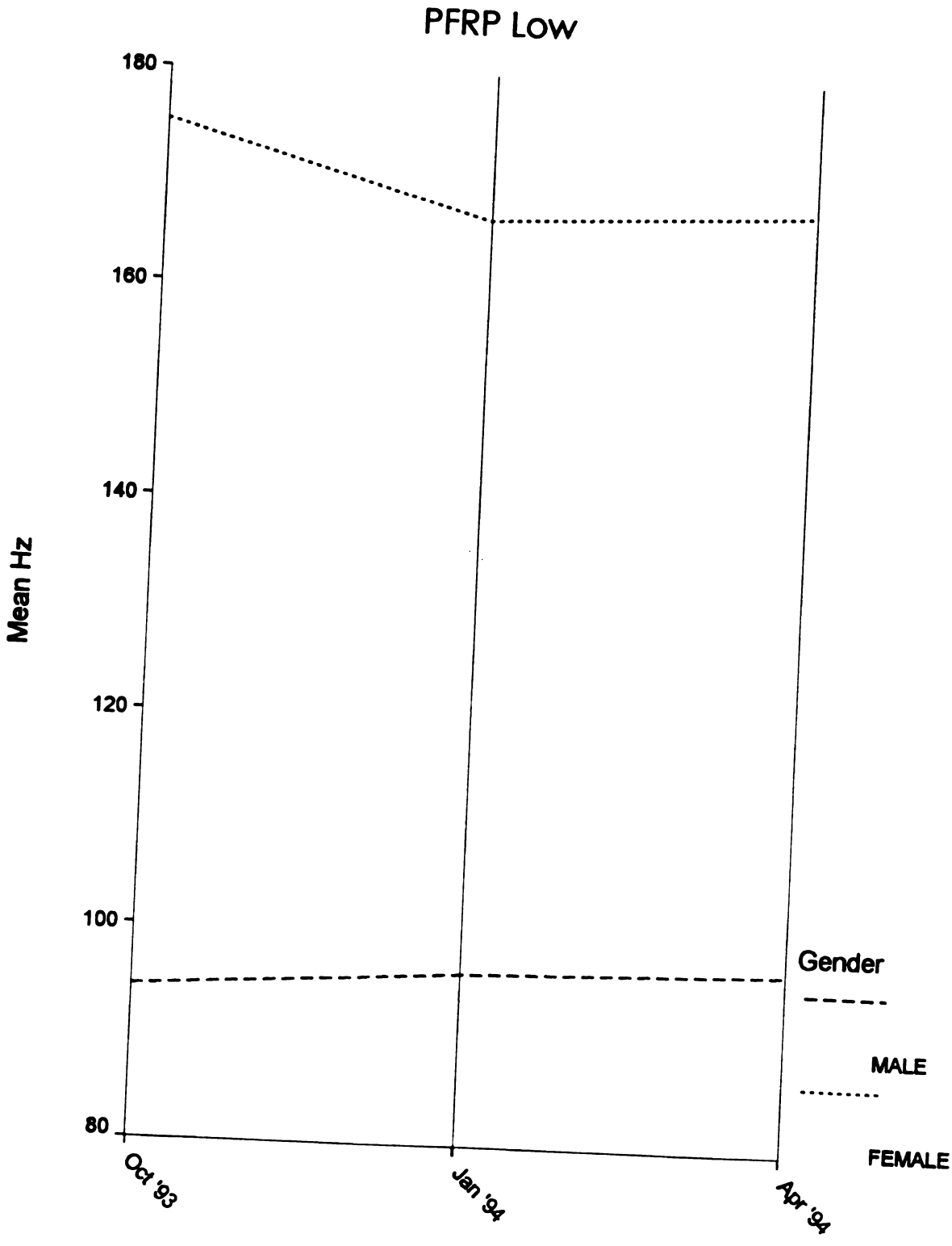

PFRP Low
180
160
140
120
100
80
Mean Hz
Oct '93
Jan '94
Apr '94
Gender
MALE
FEMALE

FIGURE 117

APPENDIX FF.4

PHYSIOLOGICAL FREQUENCY RANGE OF PHONATION - SEMITONES

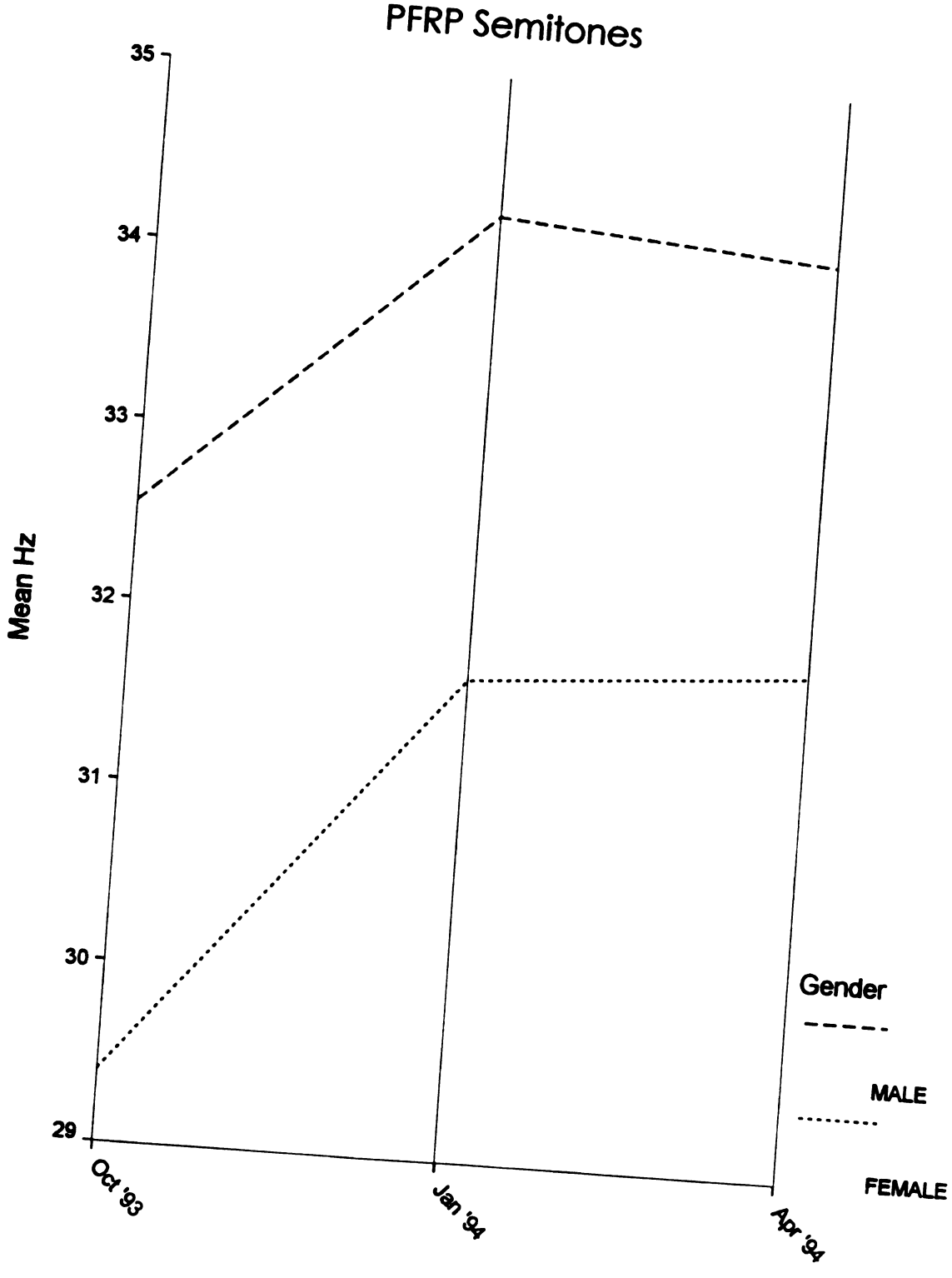

PFRP Semitones
35
34
33
32
31
30
29
Mean Hz
Oct '93
Jan '94
Apr '94
Gender
MALE
FEMALE

FIGURE 118

APPENDIX FF.5

MAXIMUM PHONATION TIME SPOKEN /a/

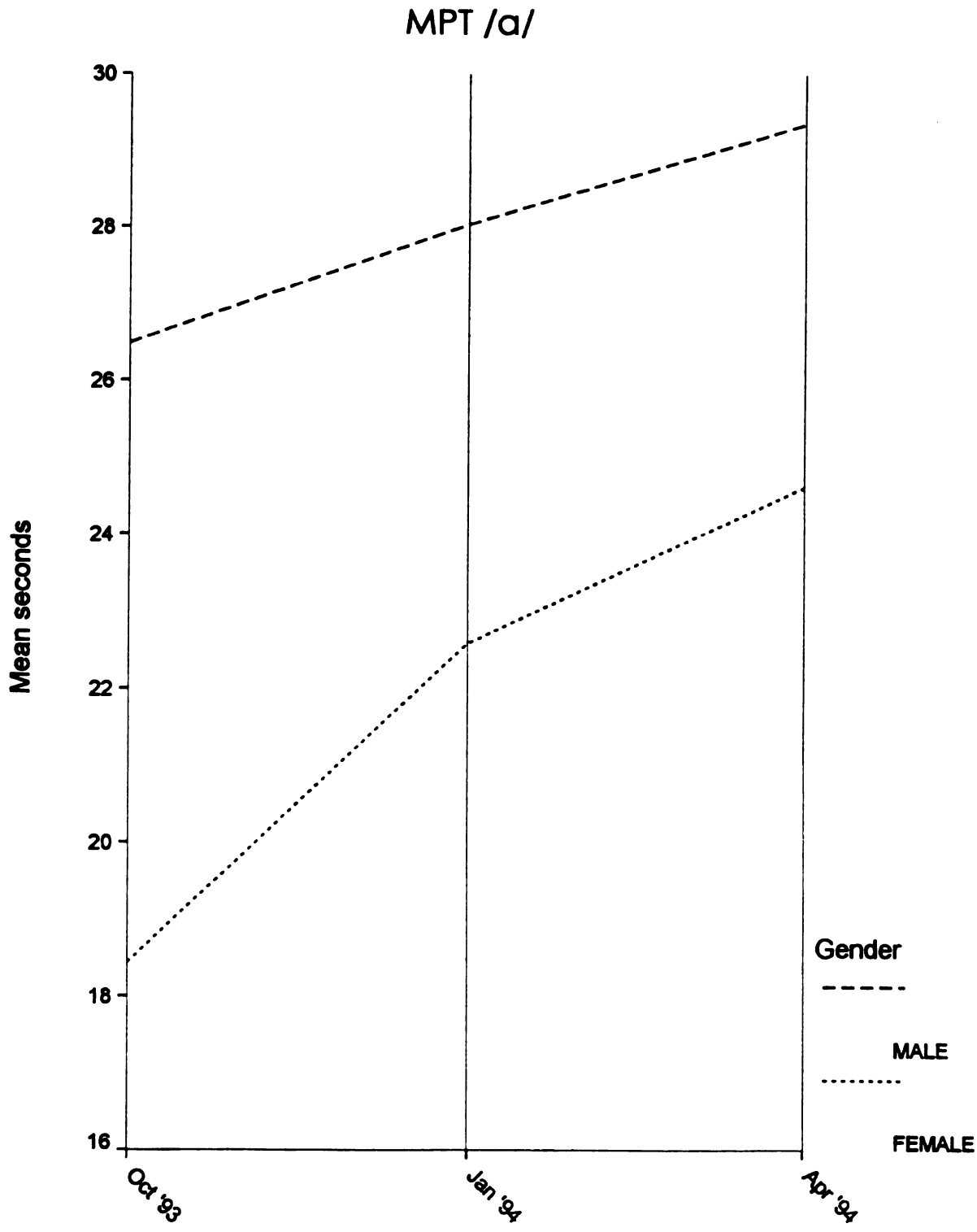

MPT /a/
30
28
26
24
22
20
18
16
Mean seconds
Oct '93
Jan '94
Apr '94
Gender
MALE
FEMALE

FIGURE 119

APPENDIX FF.6

MAXIMUM PHONATION TIME SPOKEN /i/

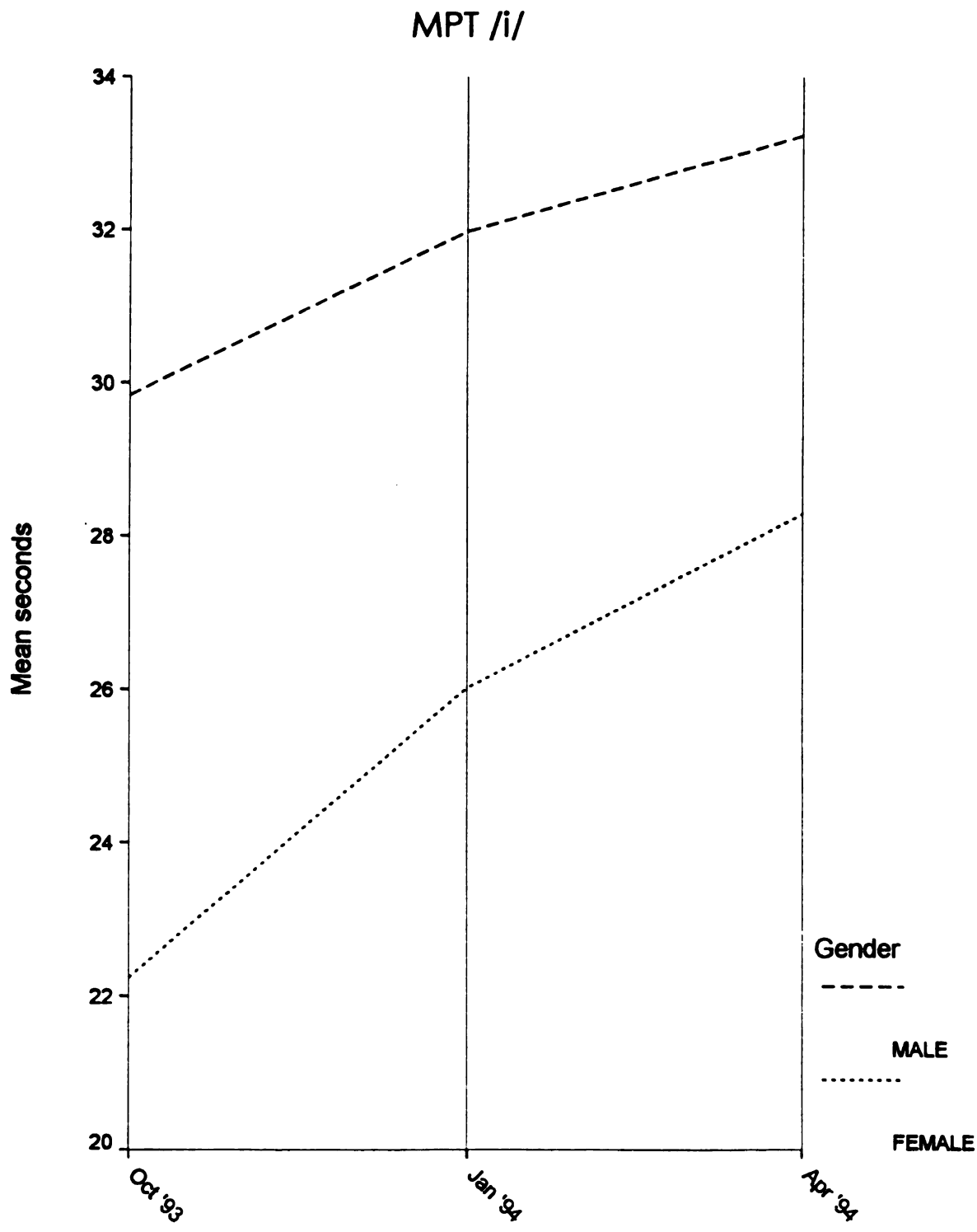

MPT /i/
34
32
30
28
26
24
22
20
Mean seconds
Oct '93
Jan '94
Apr '94
Gender
MALE
FEMALE

FIGURE 120

APPENDIX FF.7

MAXIMUM PHONATION TIME SPOKEN /u/

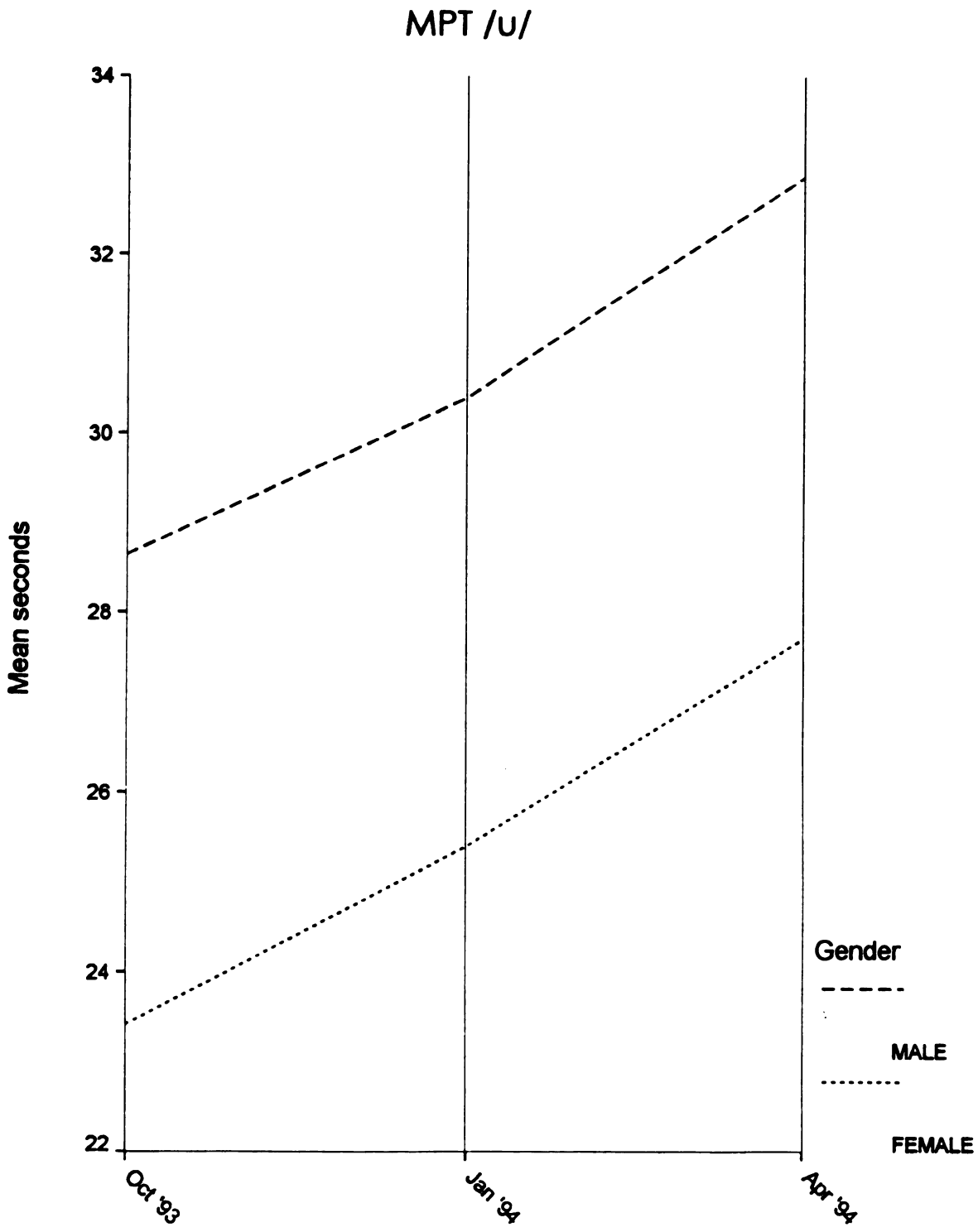

MPT /u/
34
32
30
28
26
24
22
Mean seconds
Oct '93
Jan '94
Apr '94
Gender
MALE
FEMALE

FIGURE 121

APPENDIX GG.1

MUSICAL FREQUENCY RANGE OF PHONATION - HIGH

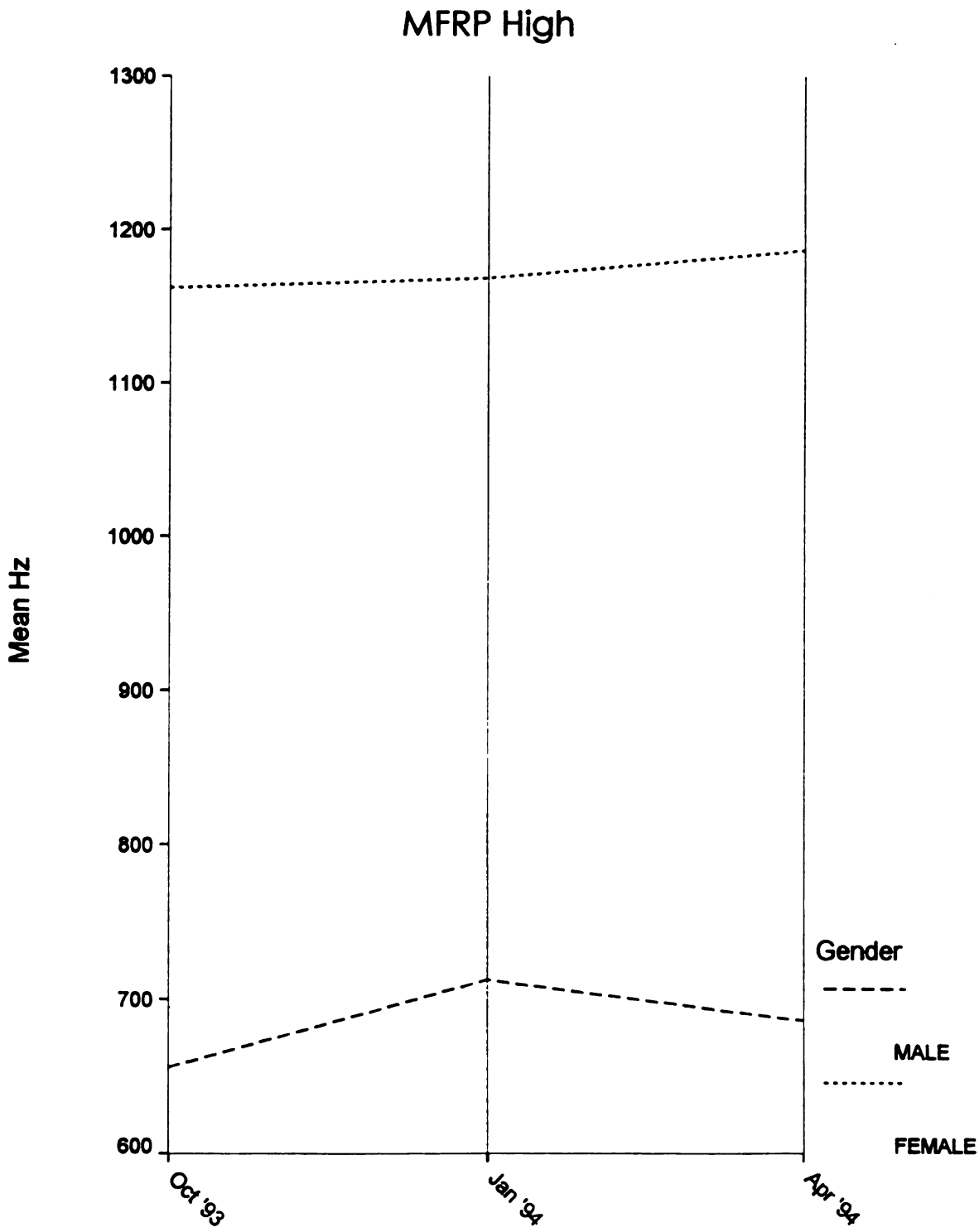

MFRP High
1300
1200
1100
1000
900
800
700
600
Mean Hz
Oct '93
Jan '94
Apr '94
Gender
MALE
FEMALE

FIGURE 122

APPENDIX GG.2

MUSICAL FREQUENCY RANGE OF PHONATION - LOW

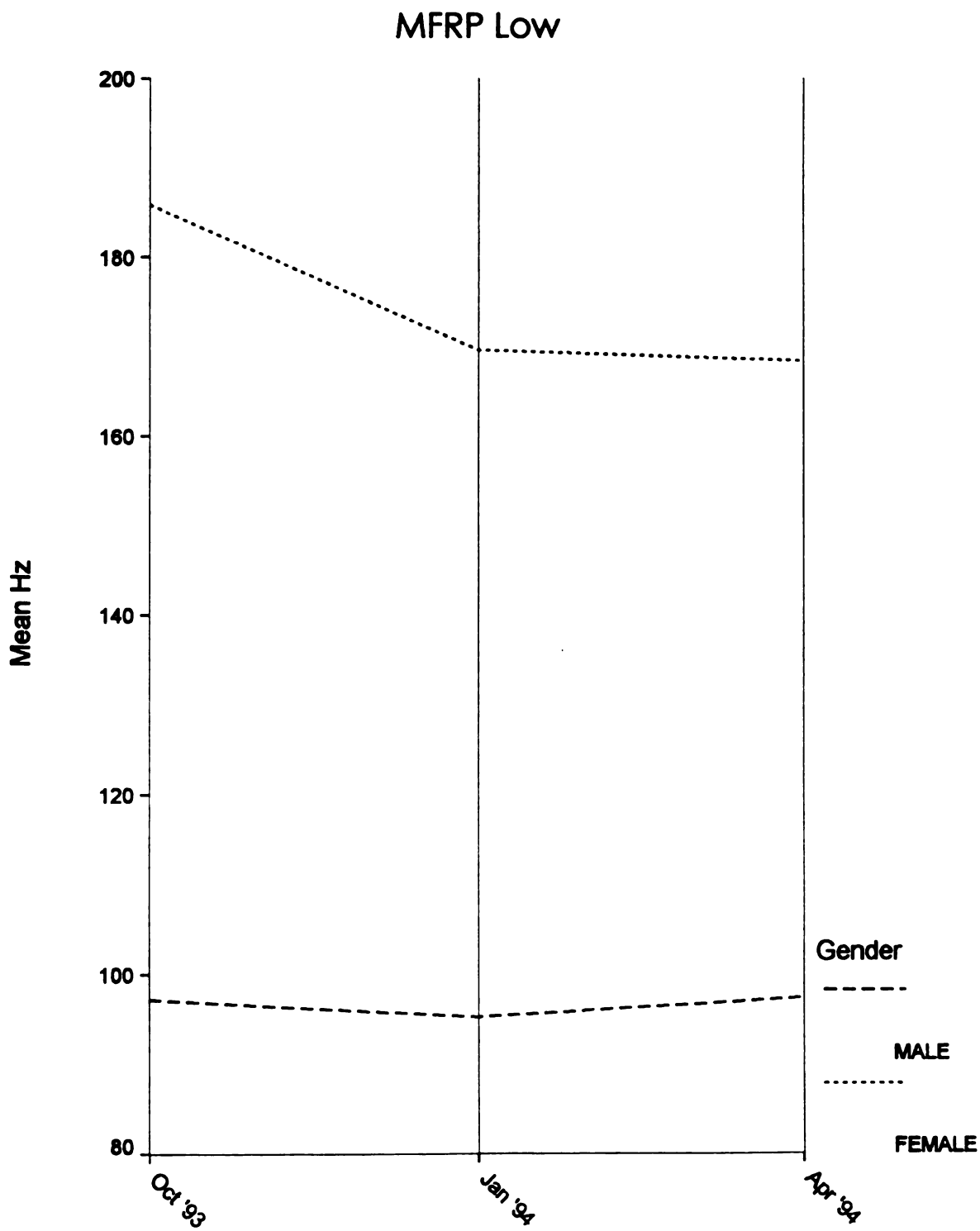

MFRP Low
200
180
160
140
120
100
80
Mean Hz
Oct '93
Jan '94
Apr '94
Gender
MALE
FEMALE

FIGURE 123

APPENDIX GG.3

MUSICAL FREQUENCY RANGE OF PHONATION - SEMITONES

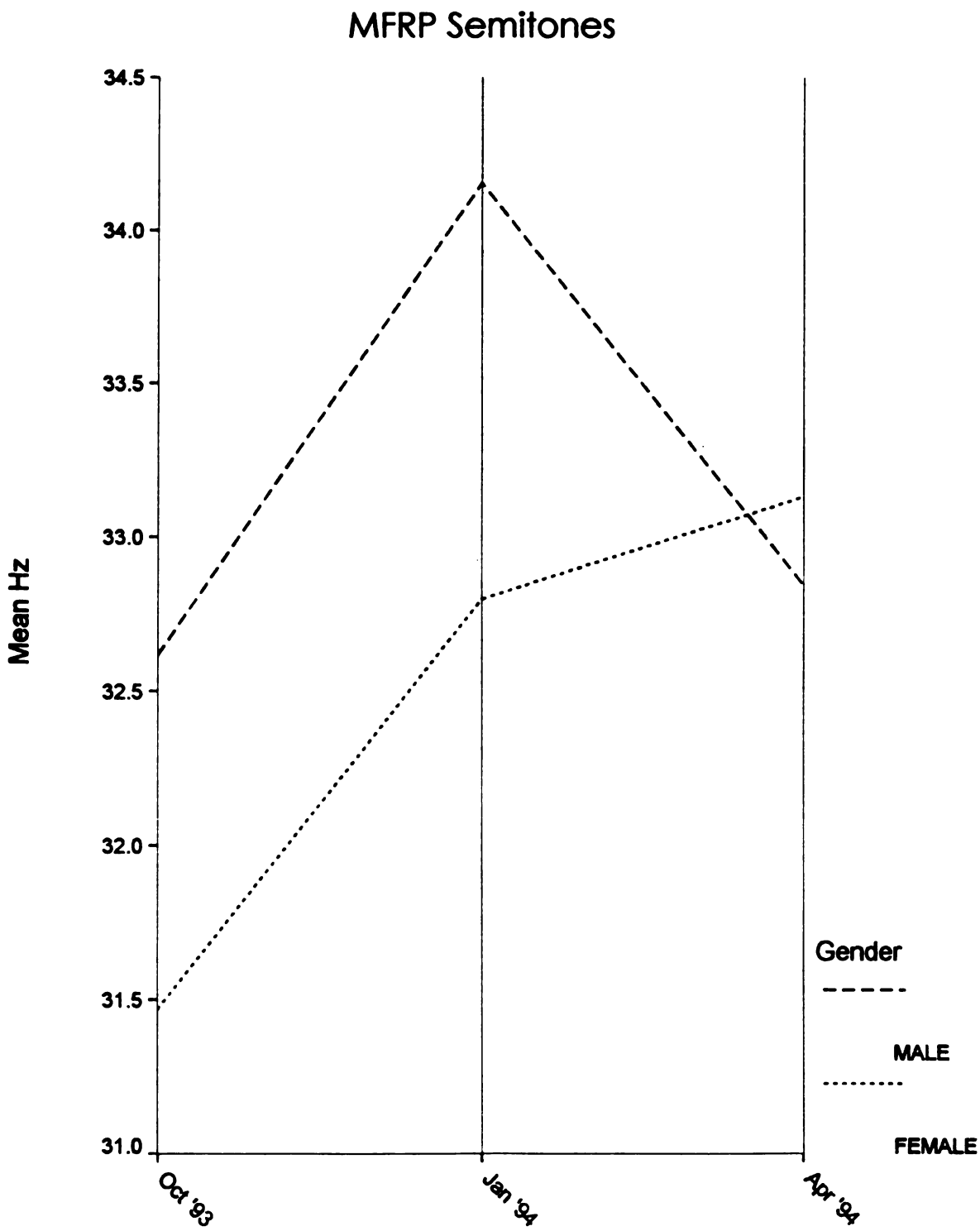

MFRP Semitones
34.5
34.0
33.5
33.0
32.5
32.0
31.5
31.0
Mean Hz
Oct '93
Jan '94
Apr '94
Gender
MALE
FEMALE

FIGURE 124

APPENDIX GG.4

MAXIMUM PHONATION TIME SUNG /a/

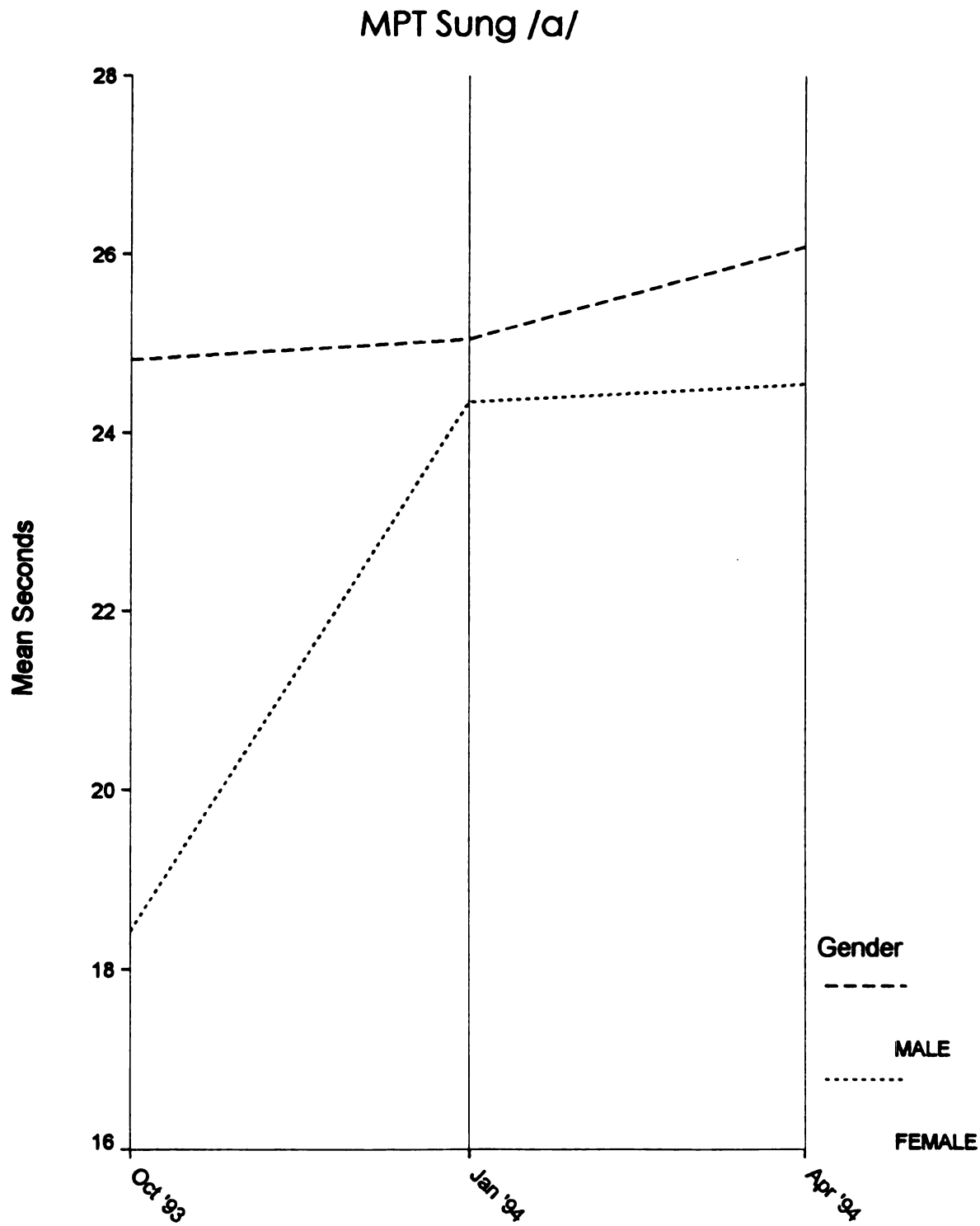

MPT Sung /a/
28
26
24
22
20
18
16
Mean Seconds
Oct '93
Jan '94
Apr '94
Gender
MALE
FEMALE

FIGURE 125

APPENDIX GG.5

MAXIMUM PHONATION TIME SUNG /i/

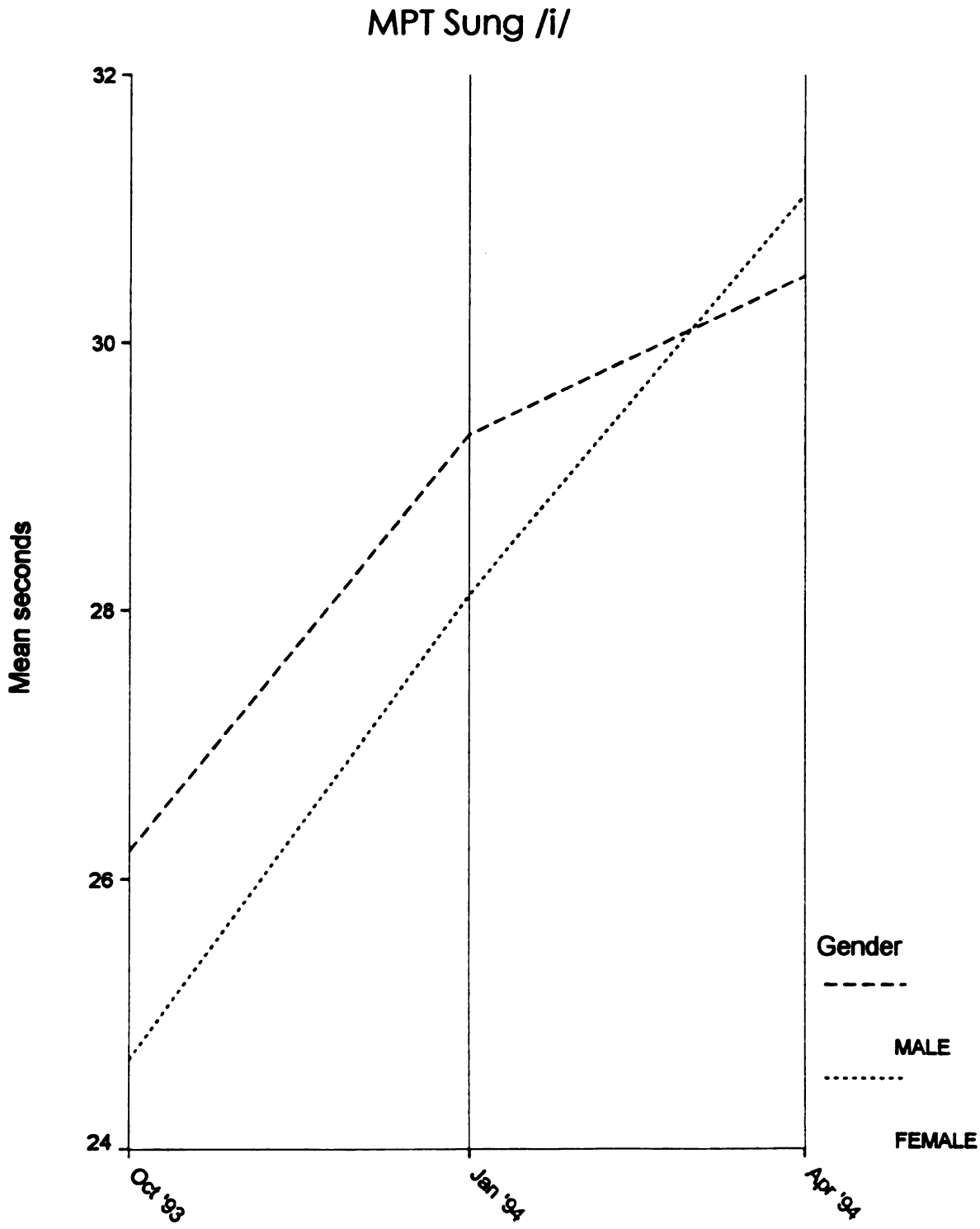

MPT Sung /i/
32
30
28
26
24
Mean seconds
Oct '93
Jan '94
Apr '94
Gender
MALE
FEMALE

FIGURE 126

APPENDIX GG.6

MAXIMUM PHONATION TIME SUNG /u/

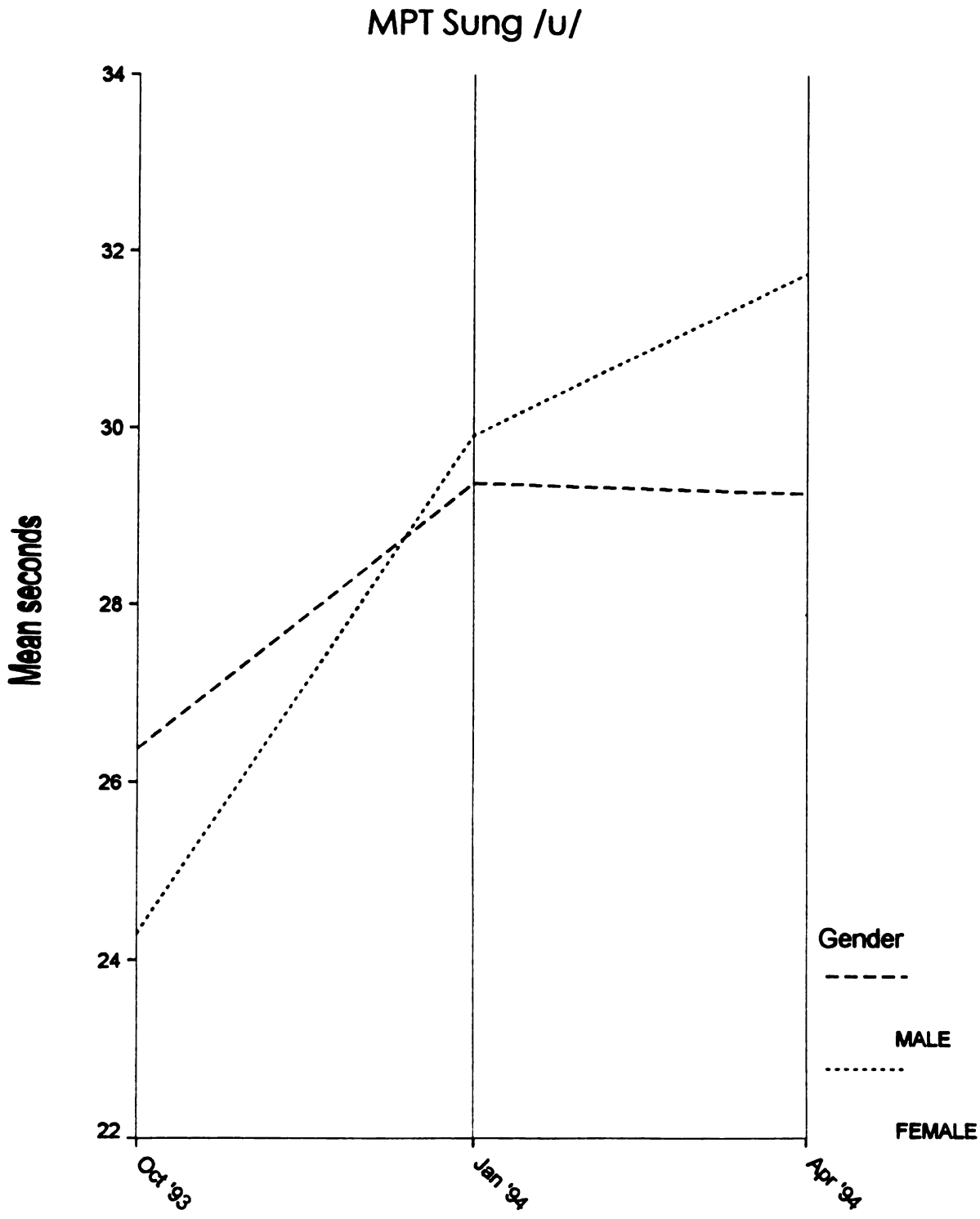

MPT Sung /u/
Mean seconds
34
32
30
28
26
24
22
Oct '93
Jan '94
Apr '94
Gender
MALE
FEMALE

FIGURE 127

APPENDIX HH.1

MAXIMUM /S/

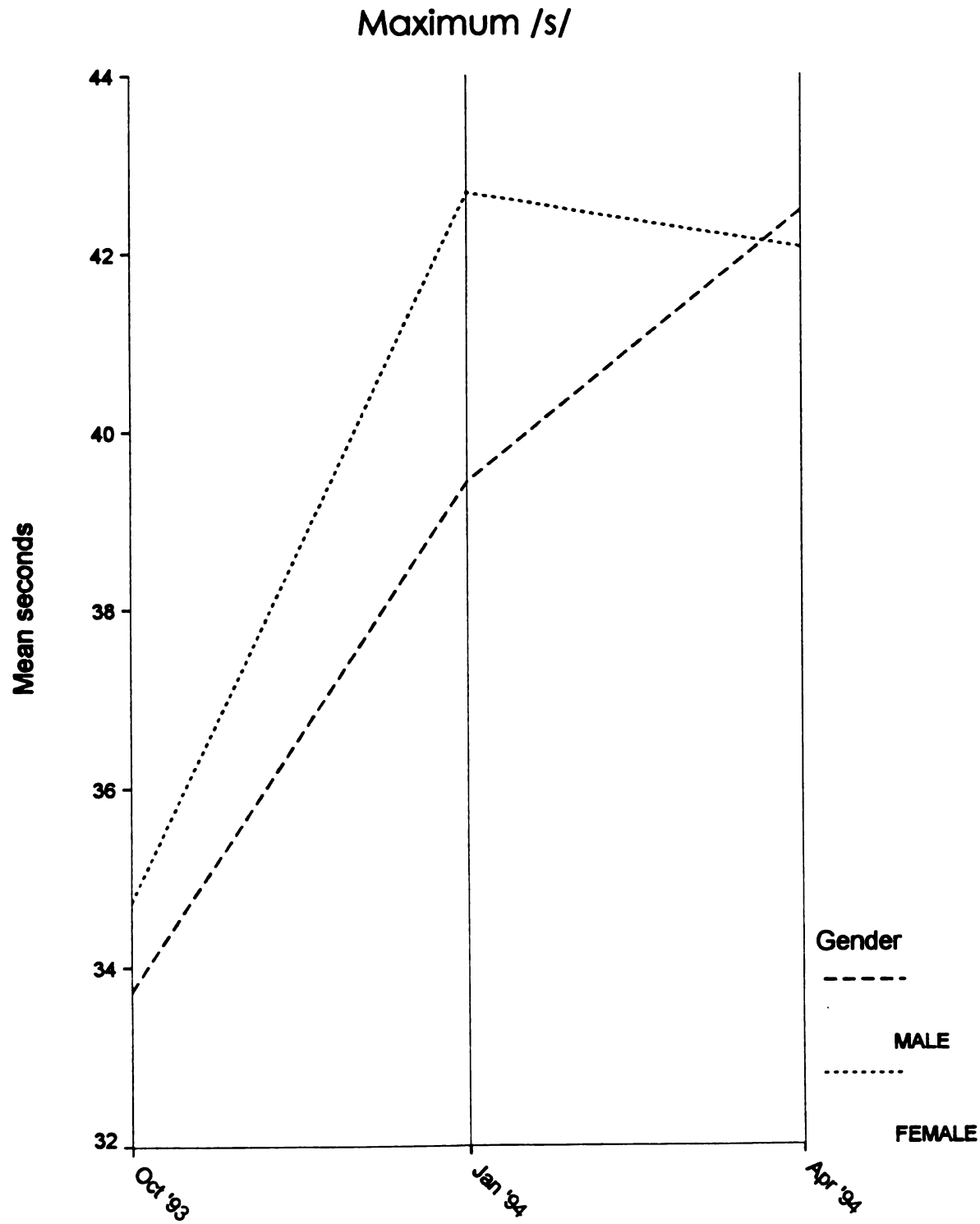

Maximum /s/
Mean seconds
44
42
40
38
36
34
32
Oct '93
Jan '94
Apr '94
Gender
MALE
FEMALE

FIGURE 128

APPENDIX HH.2

MAXIMUM /Z/

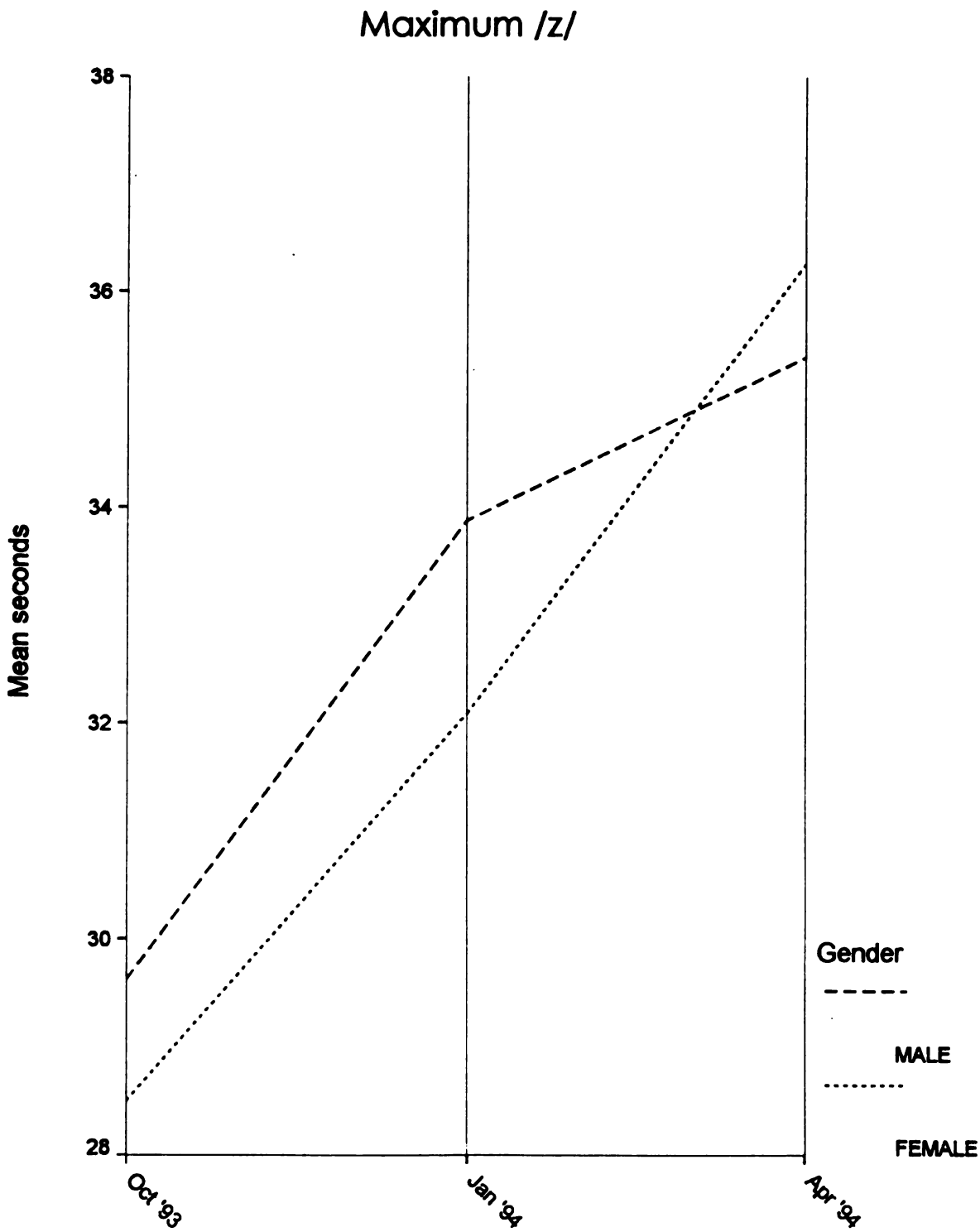

Maximum /z/
38
36
34
32
30
28
Mean seconds
Oct '93
Jan '94
Apr '94
Gender
MALE
FEMALE

FIGURE 129

APPENDIX HH.3

S/Z RATIO

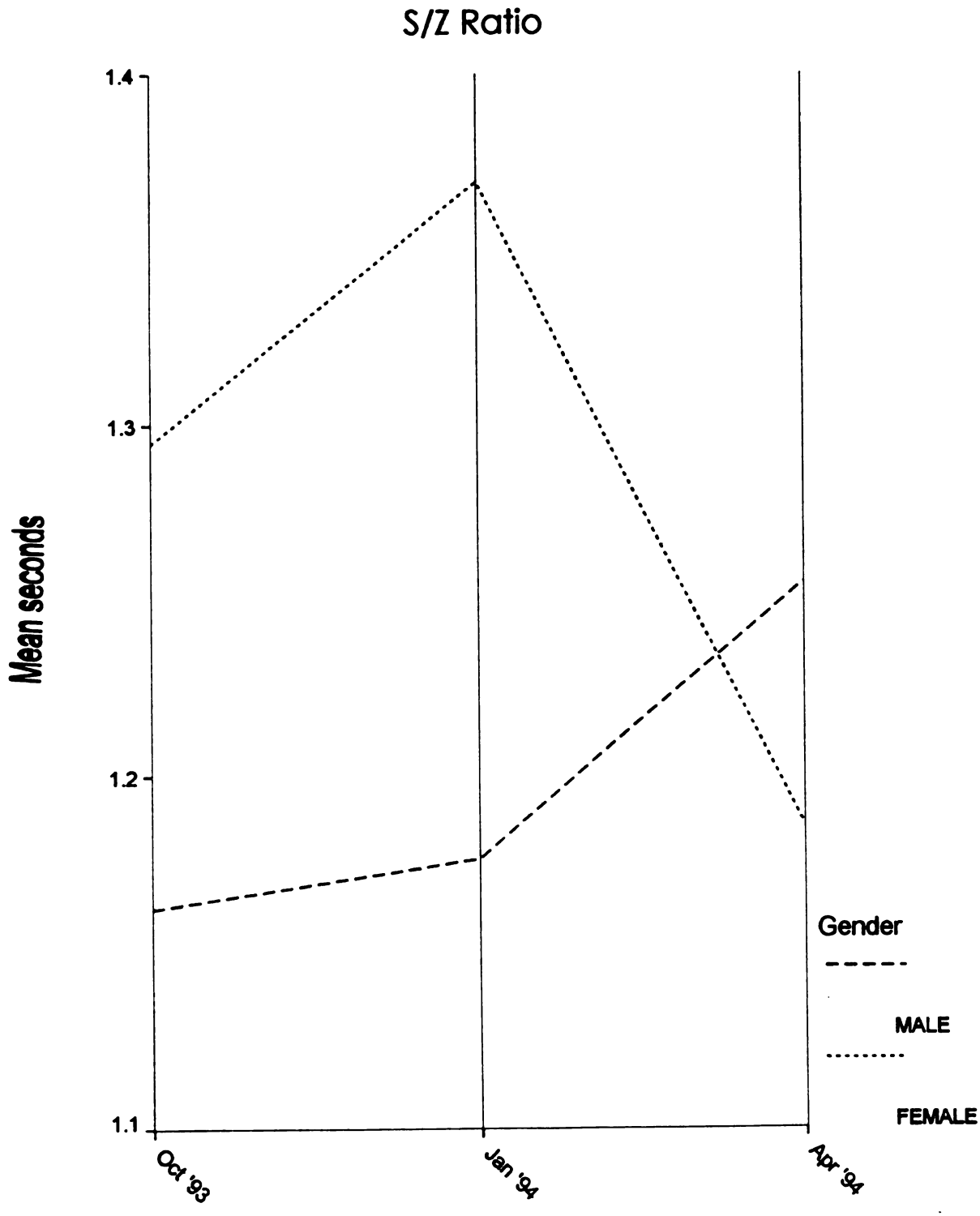

S/Z Ratio
1.4
1.3
1.2
1.1
Mean seconds
Oct '93
Jan '94
Apr '94
Gender
MALE
FEMALE

FIGURE 130

APPENDIX II.1

FORCED VITAL CAPACITY

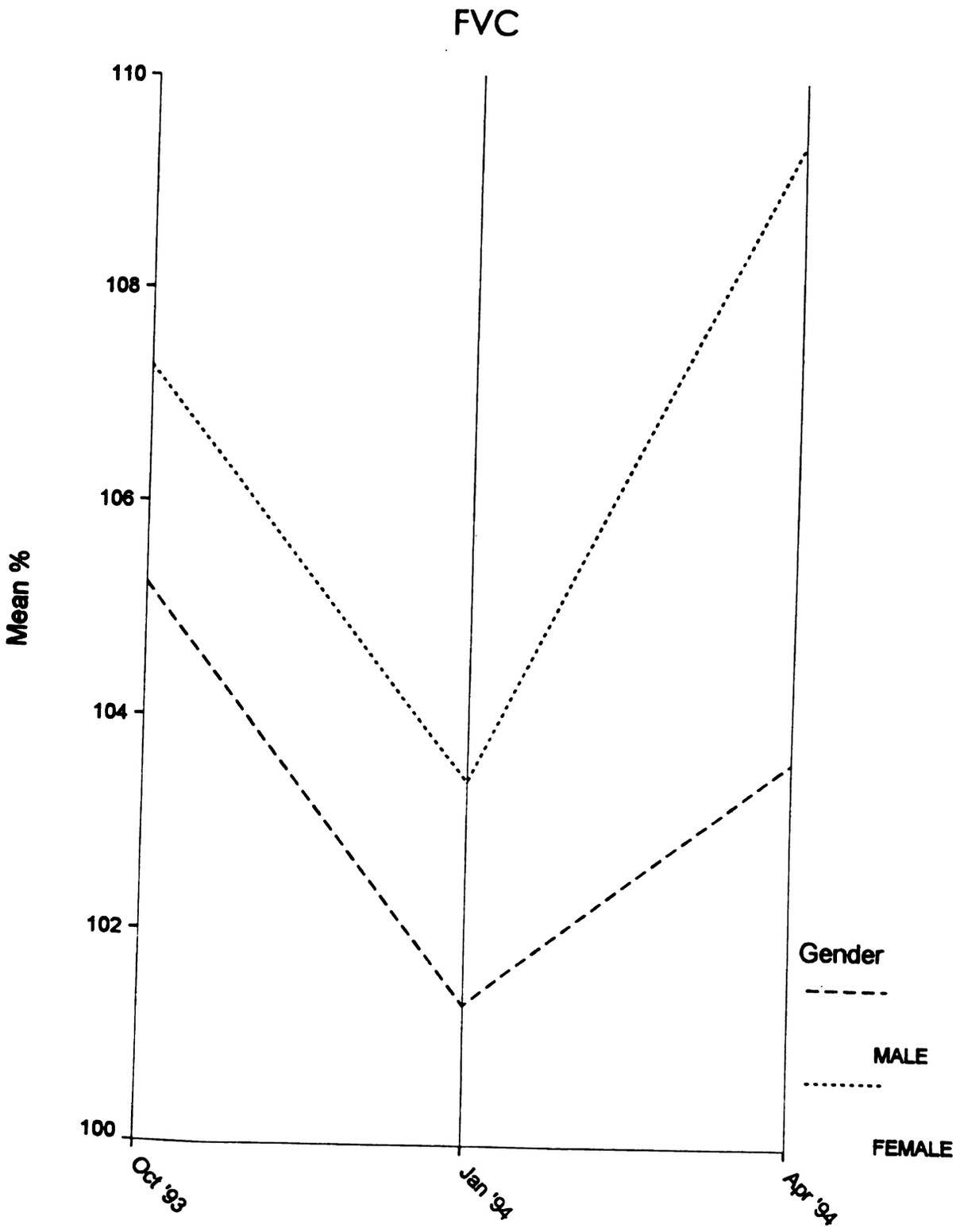

FVC
110
108
106
104
102
100
Mean %
Oct '93
Jan '94
Apr '94
Gender
MALE
FEMALE

FIGURE 131

APPENDIX II.2

FORCED EXPIRATORY VOLUME

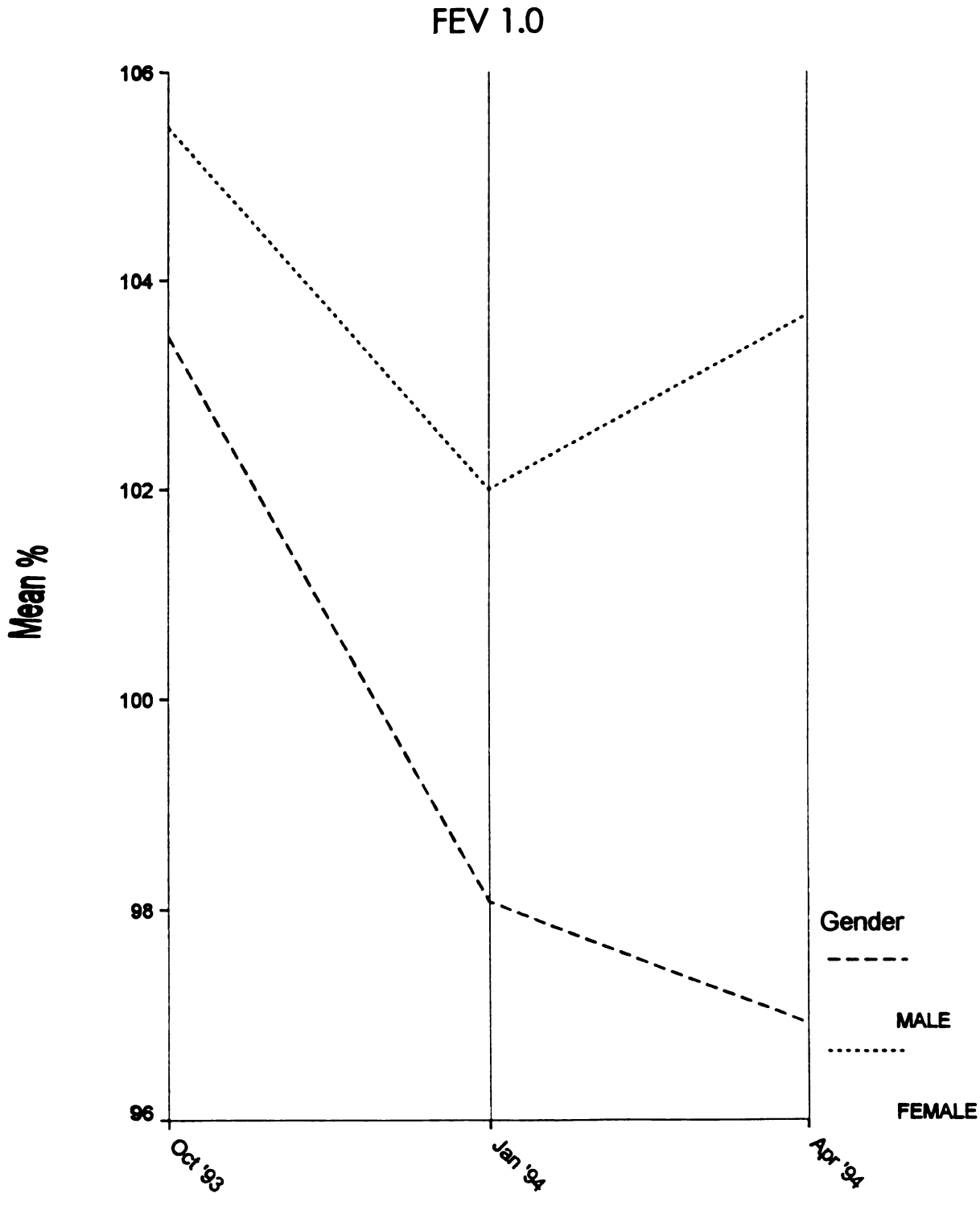

FEV 1.0
106
104
102
100
98
96
Mean %
Oct '93
Jan '94
Apr '94
Gender
MALE
FEMALE

FIGURE 132

APPENDIX II.3

FORCED EXPIRATORY FLOW

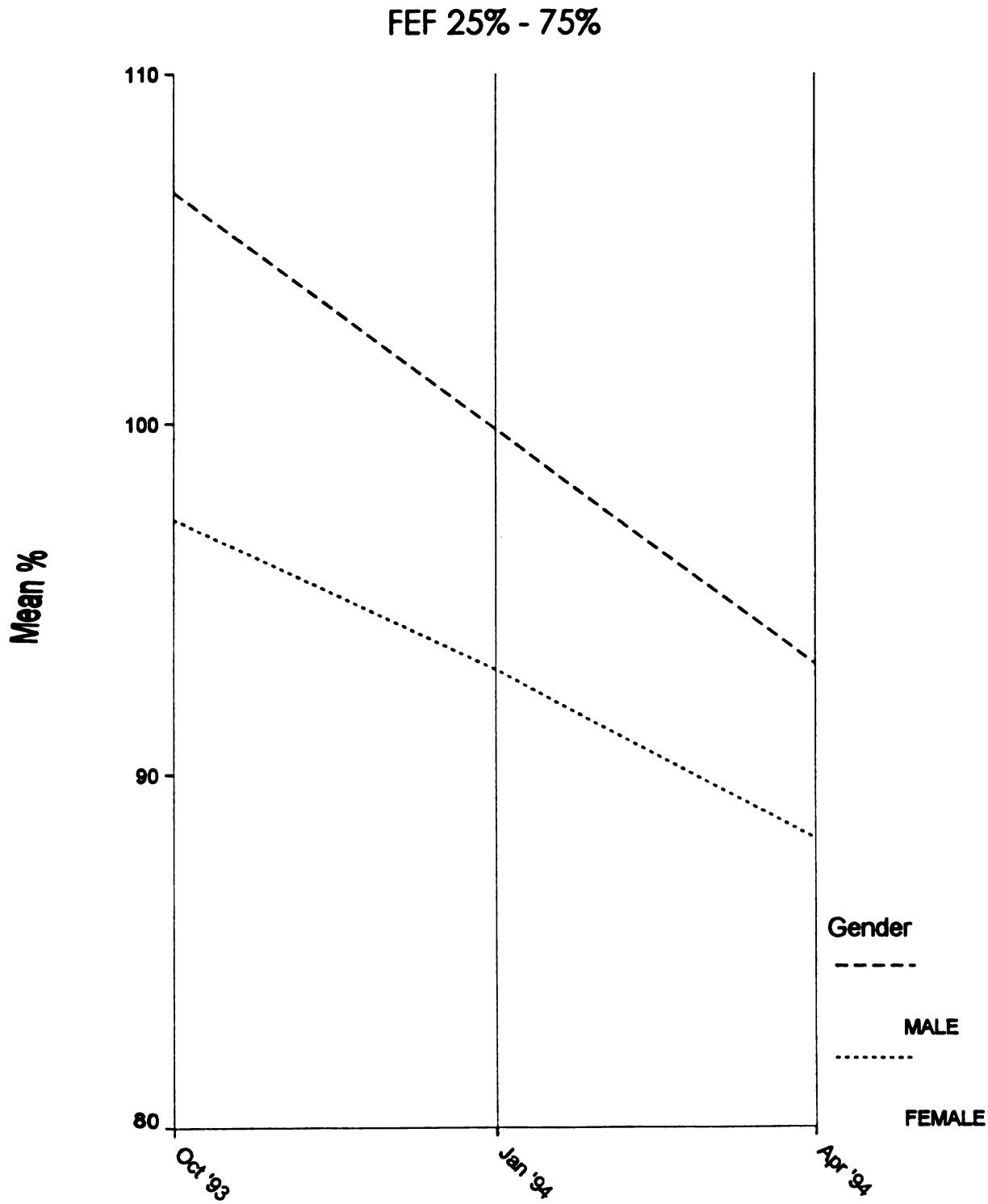

FEF 25% - 75%
110
100
90
80
Mean %
Oct '93
Jan '94
Apr '94
Gender
MALE
FEMALE

FIGURE 133

APPENDIX II.4

MEAN FLOW RATE

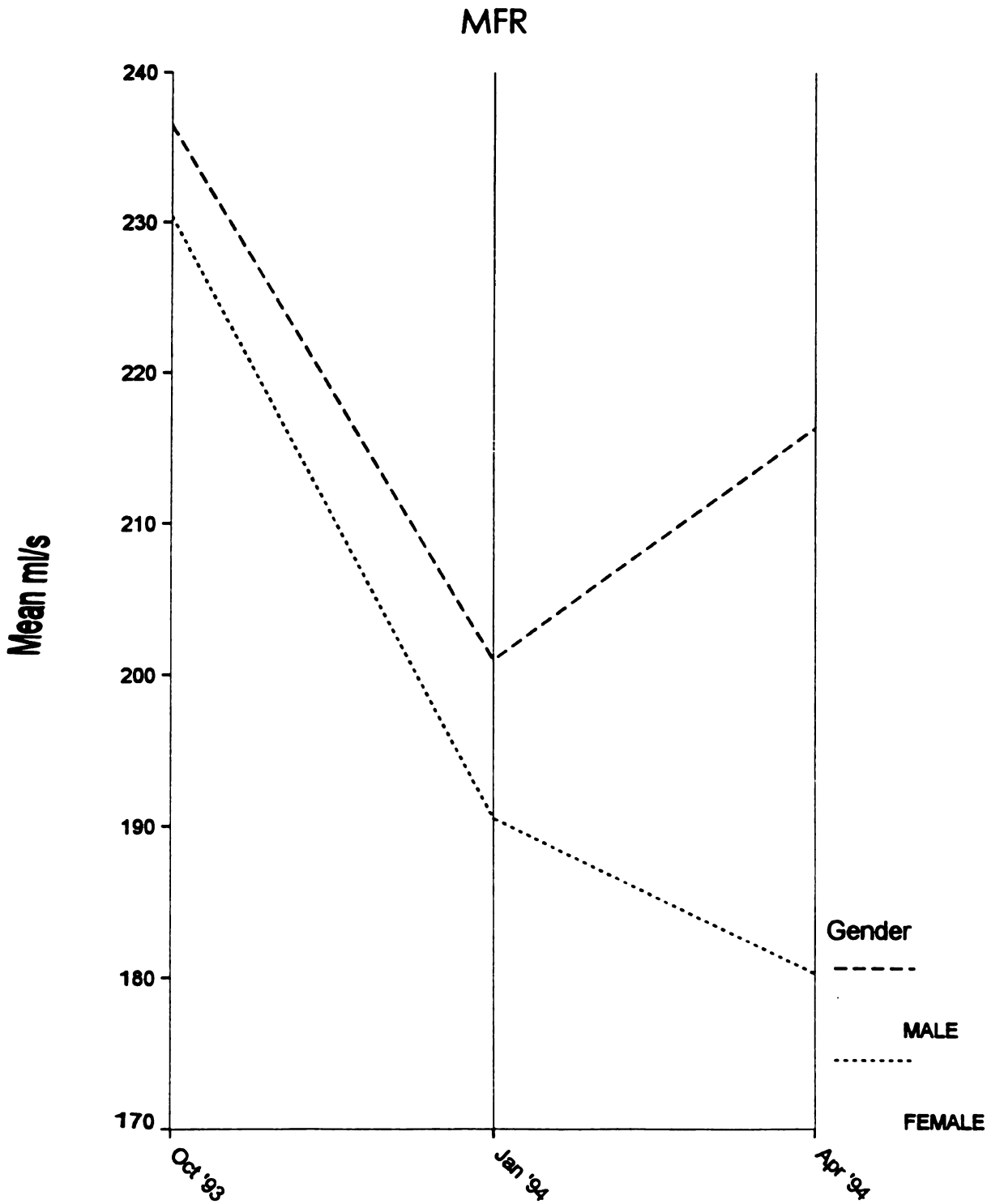

MFR
240
230
220
210
200
190
180
170
Mean ml/s
Oct '93
Jan '94
Apr '94
Gender
MALE
FEMALE

FIGURE 134

APPENDIX JJ

COMPARISON OF OBSERVED DATA WITH NORMS

MEANS AND STANDARD DEVIATIONS

Table 19

Comparison of Observed Data with Norms--Spoken /ɑ/

*COMPARISON OF OBSERVED DATA WITH NORMS

COMBINED OCCASIONS

		OBSERVED DATA		*NORM*
DOMAIN	MEASURE	MEAN	SD	NORM
Acoustic				
Spoken /ɑ/	Male Fo Hz	123.36	26.30	119.5
	Female Fo Hz	207.06	17.02	224.3
	Combined Jita us	52.52	23.63	83.2
	Combined Jitt%	0.833	0.328	1.04
	Combined RAP%	0.495	0.203	0.68
	Combined PPQ%	0.487	0.193	0.84
	Combined sPPQ%	0.680	0.176	1.02
	Combined vFo%	1.07	0.281	1.1
	Combined ShdB dB	0.301	0.115	0.35
	Combined Shim%	3.43	1.30	3.81
	Combined APQ%	2.84	1.02	3.07
	Combined sAPQ%	5.38	1.33	4.23
	Combined vAm%	11.60	2.28	8.2
	Combined NHR	0.128	0.016	0.19
	Combined VTI	0.052	0.012	0.061
	Combined SPI	11.30	4.70	14.12
	Combined FTRI%	0.347	0.109	0.95
	Combined ATRI%	4.67	1.04	4.37
	Male Fftr Hz	3.44	0.706	NA
	Male Fatr Hz	3.24	0.744	NA
	Female Fftr Hz	3.57	1.64	NA
	Female Fatr Hz	3.31	0.790	NA

* *Permission is granted with consent of the author to copy this table for experimental use and continued refinement for diagnostic purposes by Voice Scientists and Voice Technologists.*

Table 20

Comparison of Observed Data with Norms--Spoken /i/

*COMPARISON OF OBSERVED DATA WITH NORMS

COMBINED OCCASIONS

		OBSERVED DATA		*NORM*
DOMAIN	MEASURE	MEAN	SD	NORM
Acoustic				
Spoken /i/	Male Fo Hz	124.51	27.50	119.5
	Female Fo Hz	211.31	16.07	224.3
	Combined Jita us	62.48	28.53	83.2
	Combined Jitt%	1.02	0.519	1.04
	Combined RAP%	0.609	0.315	0.68
	Combined PPQ%	0.603	0.302	0.84
	Combined sPPQ%	0.748	0.267	1.02
	Combined vFo%	1.19	0.332	1.1
	Combined ShdB dB	0.220	0.057	0.35
	Combined Shim%	2.51	0.644	3.81
	Combined APQ%	1.93	0.526	3.07
	Combined sAPQ%	3.82	1.26	4.23
	Combined vAm%	8.87	2.51	8.2
	Combined NHR	0.116	0.017	0.19
	Combined VTI	0.058	0.016	0.061
	Combined SPI	7.74	4.06	14.12
	Combined FTRI%	0.331	0.091	0.95
	Combined ATRI%	3.65	1.25	4.37
	Male Fftr Hz	4.61	1.88	NA
	Male Fatr Hz	3.17	0.704	NA
	Female Fftr Hz	3.61	1.36	NA
	Female Fatr Hz	3.44	0.760	NA

* *Permission is granted with consent of the author to copy this table for experimental use and continued refinement for diagnostic purposes by Voice Scientists and Voice Technologists.*

Table 21

Comparison of Observed Data with Norms--Spoken /u/

* COMPARISON OF OBSERVED DATA WITH NORMS COMBINED OCCASIONS				
		OBSERVED DATA		*NORM*
DOMAIN	MEASURE	MEAN	SD	NORM
Acoustic				
Spoken /u/	Male Fo Hz	127.32	30.14	119.5
	Female Fo Hz	213.59	15.11	224.3
	Combined Jita us	53.83	13.35	83.2
	Combined Jitt%	0.549	0.197	0.68
	Combined PPQ%	0.536	0.176	0.84
	Combined sPPQ%	0.672	0.151	1.02
	Combined vFo%	1.05	0.215	1.1
	Combined ShdB dB	0.139	0.040	0.35
	Combined Shim%	1.59	0.447	3.81
	Combined APQ%	1.34	0.470	3.07
	Combined sAPQ%	3.53	1.68	4.23
	Combined vAm%	8.19	2.71	8.2
	Combined NHR	0.109	0.014	0.19
	Combined VTI	0.028	0.005	0.061
	Combined SPI	47.53	20.35	14.12
	Combined FTRI%	0.307	0.099	0.95
	Combined ATRI%	3.41	1.27	4.37
	Male Fftr Hz	4.12	2.04	NA
	Male Fatr Hz	3.08	0.612	NA
	Female Fftr Hz	3.43	0.931	NA
	Female Fatr Hz	3.12	0.546	NA

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Table 24

Comparison of Observed Data with Norms--Sung /u/

* COMPARISON OF OBSERVED DATA WITH NORMS COMBINED OCCASIONS				
		OBSERVED DATA		*NORM*
DOMAIN	MEASURE	MEAN	SD	NORM
Acoustic				
Sung /u/	Male Fo Hz	175.07	35.10	119.5
	Female Fo Hz	399.64	103.69	224.3
	Combined Jita us	40.60	21.32	83.2
	Combined Jitt%	0.981	0.318	1.04
	Combined RAP%	0.562	0.195	0.68
	Combined PPQ%	0.572	0.196	0.84
	Combined sPPQ%	1.45	0.811	1.02
	Combined vFo%	1.93	0.694	1.1
	Combined ShdB dB	0.185	0.074	0.35
	Combined Shim%	2.06	0.843	3.81
	Combined APQ%	2.33	1.27	3.07
	Combined sAPQ%	7.24	2.74	4.23
	Combined vAm%	11.93	3.22	8.2
	Combined NHR	0.103	0.036	0.19
	Combined VTI	0.030	0.016	0.061
	Combined SPI	44.23	28.75	14.12
	Combined FTRI%	1.34	0.728	0.95
	Combined ATRI%	7.11	2.58	4.37
	Male Fftr Hz	4.72	0.449	NA
	Male Fatr Hz	4.76	0.475	NA
	Female Fftr Hz	4.86	0.536	NA
	Female Fatr Hz	4.93	0.568	NA

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Table 25

Comparison of Observed Data with Norms--Phonatory Measures

* COMPARISON OF OBSERVED DATA WITH NORMS COMBINED OCCASIONS				
		OBSERVED DATA		*NORM*
DOMAIN	MEASURE	MEAN	SD	NORM
Phonatory				
Male	PFRP-Low	95.72 Hz	15.68	80.1 Hz
	PFRP-High	691.92 Hz	125.85	674.6 Hz
	PFRP-Semitones	33.61 Hz	2.91	35 Hz
	MFRP-Low	96.61 Hz	12.34	84.5 Hz
	MFRP-High	684.69 Hz	122.94	682.9 Hz
	MFRP-Semitones	33.20 Hz	2.48	35 Hz
	Average Fo	126.73 Hz	21.14	119.5 Hz
	MPT /a/	27.95 s	6.97	34.6 s
	MPT /i/	31.68 s	9.25	29.89 s
	MPT /u/	30.63 s	9.13	29.96 s
	MPT Sung /a/	25.31 s	6.9	24.26 s
	MPT Sung /i/	28.67 s	9.9	26.95 s
	MPT Sung /u/	28.33 s	8.09	26.95 s
	S/Z Ratio	1.19	0.285	1
Female	PFRP-Low	169.73 Hz	20.40	140.2 Hz
	PFRP-High	1035.62 Hz	64.58	1121.5 Hz
	PFRP-Semitones	30.95 Hz	2.20	35 Hz
	MFRP-Low	174.59 Hz	19.15	139.2 Hz
	MFRP-High	1171.99 Hz	117.90	1109.2 Hz
	MFRP-Semitones	32.46 Hz	1.61	35 Hz
	Average Fo	210.79 Hz	19.34	224.3 Hz
	MPT /a/	21.88 s	5.80	25.7 s
	MPT /i/	25.51 s	7.06	24.5 s
	MPT /u/	25.50 s	7.35	22.69 s
	MPT Sung /a/	22.43 s	8.54	17.46 s
	MPT Sung /i/	27.95 s	10.67	20.59 s
	MPT Sung /u/	28.65 s	11.49	20.73 s
	S/Z Ratio	1.28	0.216	1

Table 26

Comparison of Observed Data with Norms--Respiratory Measures

* COMPARISON OF OBSERVED DATA WITH NORMS COMBINED OCCASIONS				
		OBSERVED DATA		*NORM*
DOMAIN	MEASURE	MEAN	SD	NORM
Respiratory				
Male	FVC	103.38%	12.67	100%
	FEV 1.0	99.48%	18.16	100%
	FEF 25-75%	99.87%	53.81	100%
	MFR	217.94 ml/s	72.35	101 ml/s
Female	FVC	106.68%	13.11	100%
	FEV 1.0	103.71%	12.61	100%
	FEF 25-75%	92.82%	20.37	100%
	MFR	200.41 ml/s	42.46	92 ml/s

* *Permission is granted with consent of the author to copy this table for experimental use and continued refinement for diagnostic purposes by Voice Scientists and Voice Technologists.*

MDVP DIAGRAM
(Sustained Phonation of Spoken /a/)

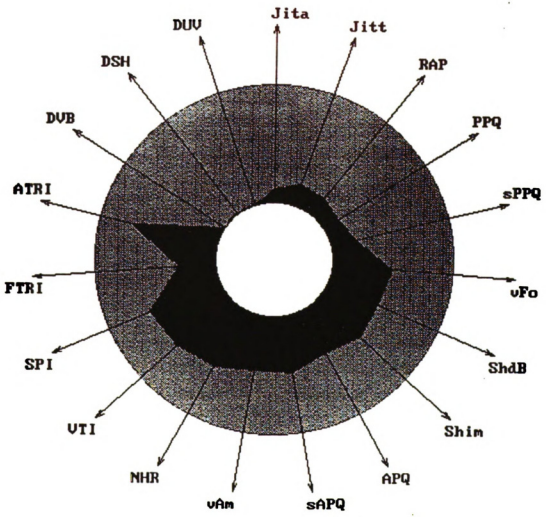


Figure 135

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