ACOUSTIC ANALYSIS OF EKEGUSII VOWELS AND STOPS

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ABSTRACT

Preceding a theoretical exploration of issues in a language is a basic research. Through such basic descriptive study, the vitality of the language is aided and documented. This is vital especially for the less studied languages such as EkeGusii that has not been phonetically studied and documented especially using scientific methods. Following Peterson and Barney (1952), this work is an acoustic study of the vowels and voiceless stops of Ekegusii. Its goal is to transcend the impressionistic descriptions previously in the 1960s by Whiteley (1965) and Guthrie (1967). Specifically, the work explores the seven vowels of Ekegusii /i e ɛ a ɔ o u/ along with the intervening voiceless stops /p t k/ within the Source-Filter Theory of sound production. The purpose of this study is to give a complete description of the vowels and stops and document them for reference by various fields from linguistics to machine translation. The scope of impressionistic phonetics is limited by capabilities of human senses and is not verifiable while experimental phonetics like this present study extends and backs-up impressionistic description. The main objective of this study is to give a complete description of the acoustic qualities of the vowels and stop consonants from the oral data got from a purposively selected sample of twelve (four males, four females and four children), bearing in mind their speech mannerisms, geographical and dialectal considerations. Audio data was recorded as the informants read out word lists and carrier phrases bearing target sounds into a microphone connected to a computer running on Praat sampled at 44100 Hz. Analysis of audio data is primarily done using Praat software. Further, quantitative data analyses were done using MS-Excel spread sheets and SPSS with the results presented in tables, charts and written descriptions for each sound, each subject and group. The study mainly found out that EkeGusii adopts a seven vowel system with length contrast making the vowels to be phonologically fourteen. The vowels also display age, sex and dialectal variations. Results for stop consonants show that stops can be discriminated by features such as voice-onset-time, burst intensity and stop duration. Significantly, the research findings provide useful basis for codification and documentation of EkeGusii phonetics for the two dialects.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

One day in early 2002, a newly posted education officer for Gucha District, South Western Kenya, who did not speak the local language, was delivering her maiden address to teachers under her new domain. She had prepared her speech well with the main aim of urging the teachers to do all in their power to help learners in their respective schools as their performance was wanting. She must have asked somebody to tell her the local word for 'helping' **kɔ:ɲa** since I noticed that she referred to her notes before speaking it out. Instead of saying **kɔ:ɲa** she said **kɔɲa** 'to defile' and there was a burst of laughter all-over the room with some ladies covering their faces in embarrassment. The chosen word which they heard borders on taboo. That is Ekegusii language for you where, a simple lengthening or shortening of the vowel sound is contrastive to the native speakers of Ekegusii. She had the error corrected but at a cost! If vowel length can be so definitive, then there are a number of other discrete qualities that when invoked in Ekegusii create huge phonetic contrasts. But, how long or how short is a vowel sound? Can it be measured and quantified? These information are important and they are only obtainable from a careful, scientific study of a language in place of mere impressionistic approach which becomes quite subjective. Phonetics, the study of the physical properties of speech offers guidance on how to scientifically describe the speech sounds of a language. The linguistic subfield of acoustic phonetics has gained currency as a quantitative science in linguistics as it allows us to quantify our claims on the speech sounds noting that sounds are varied and organized in time sequence subject to contextual influences.

As already mentioned, Ekegusii has been studied by scholars; however, these existing studies were limited in their scope especially due to their reliance on subjective impressions. There is therefore need to provide a more reliable description of the speech sounds. The works done on EkeGusii are mostly on the phonology of the language and were not as a result of instrumental analyses. They include studies done by Guthrie (1948, 1967) who classified Ekegusii among other Bantu languages; Bosire (1993) had a comparative study of the dialects of Ekegusii; Bickmore (1998) studied the Dahl's law in the language; Cammenga (2002) did a study on the phonology and morphology; Mecha (2006) studied the phonology and morphology of Ekegusii; Odero (2008) studied tense and aspect; Omoke (2012) analyzed sense relations in Ekegusii; Basweti, Barasa and Michira (2015) researched on syntax among others.

The aim of this study is to give a detailed systematic description of Ekegusii vowels and stop consonants. To try and achieve this, it will be important to look at the premier work on Ekegusii language done by Whiteley (1965) as a starting point. He identified and described Ekegusii vowel and consonant sounds impressionistically, that is, relying on senses only to describe sounds. Impressionistic description as much as it has been used is deficient while acoustic studies rely on instruments that cannot miss out on any quality as set. This study builds on the work done by Whitely and departs from his impressionistic approach to using quantitative instruments of analyses.

From the literatures, early acoustic work was carried out by Peterson and Barney (1952). They recorded words bearing ten target vowels in /hVd/ context from seventy-six informants (adult males, adult females and children) making summaries of average values of fundamental frequency or pitch (hence forth F0), first formant (henceforth F1), second formant (henceforth F2), and third formant (henceforth F3). By these, they were able to plot F2-F1 thus coming up with a vowel chart. Their results showed that children have higher formants than adult females (henceforth females) and both have higher formants than adult males (henceforth males). As such there are differences in the speech acoustics due to sex and age as a function of vocal tract and vocal cords. This study applied the lead by Peterson & Barney (1952) to explore speech sounds of adult males and females as well as children in Ekegusii.

Another study of interest to this present work was that done by Hillenbrand, Getty, Clark and Wheeler (1995) who did a simulation Peterson & Barney's (1952) study in more précis; they added duration measurements and controlled dialectical differences which was significant to Ekegusii where duration and dialectal variation have been reported. Ekegusii has two distinct dialects as per the literature (Mecha 2006). Hillenbrand, Getty, Clark and Wheeler (1995) had almost the same results as Peterson & Barney (1952) on vowel formants. Following the procedure of Hillenbrand, Getty, Clark and Wheeler (1995), the present study examined the qualities of vowels: F0, F1, F2, F3 and duration. Also, stop consonants were described in terms of their closure duration, voice onset time (VOT), burst intensity, fundamental frequency of vowel after the stop consonant and second formant transitions of following vowel after stop consonant. The aforementioned qualities of vowels and stop consonants were measured for words in citation form and in running speech.

Theoretically, this study was analysed on the backdrop of the Source-filter theory which explains how we can interpret the various aspects of a sound wave from its source at the vocal cords through the passages and out into the atmosphere. The various manipulations that air waves undergo produce the sound quality described herein.

Ekegusii is a Bantu language spoken by the Abagusii who reside in Kisii and Nyamira counties (Basweti, Barasa and Michira 2015). The term Ekegusii is composed of prefix Eke- which means 'belonging to' and Gusii which refers to the land or the people hence EkeGusii can directly be translated to be 'that belongs to Gusii' or 'language of the Gusii'. According to the 2009 National Census, EkeGusii has an estimated number of native speakers totalling 2.2 million. The AbaGusii are believed to have migrated from the Congo forest in the 1400s through Uganda entering Kenya through the Western part of the country. They are believed to be descendants of Mogusii (Ochieng' 1974) and his sons form the six main clans of the community, that is, Getutu, Mogirango, Monchari, Mobasi, Machoge and Nyaribari. They are bordered to the East by the Kipsigis, to the West by the Luo, and to the South by the Maasai, all of whom are Nilotic speakers. They do not neighbour any Bantu speakers.

Guthrie (1967) in his zonal classification of languages classifies EkeGusii as a central Bantu language part of the sub-family of the Kuria language labeled E. 42. He relates it to other languages including: Lulogooli, Ameru (Kenya) Kuria (Kenya and Tanzania) Ware, Ikizu, Ikoma, and Sanjo (Tanzania). Just like the majority of Bantu languages, Ekegusii is a tone language (Nurse and Gerard 2003).

There has been a long debate on the existence of dialects in Ekegusii, Bosire (1993) and Mecha (2006) classify EkeGusii into two dialects, the Rogoro and the Maate dialect. The main difference between these two dialects is in vocabulary and pronunciation. The Rogoro dialect is mainly spoken in the northern parts of Gusiiland while the Maate dialect is mainly spoken in the southern parts of Gusiiland. The Rogoro dialect is considered to be the standard form because it is the one used in print, taught in schools and used in news broadcast in Ekegusii (Omoke 2012).

According to Guthrie (1967) and Whiteley (1965), Ekegusii language has seven vowels as /i e ɛ a ɔ o u/. The same vowel inventory is reported in related languages as Higgins (2012) notes of

Ikoma, a Bantu JE45 (Maho 2003) found in the Serengeti district of the Mara region North-West of Tanzania; each of these vowels has a phonemic long vowel counterpart like it is in Ekegusii.

A more recent study done by Bickmore (1998) confirms the same IPA notation like Whiteley. On his part, Cammenga (2002) points out that such a notation is not exhaustive. What Cammenga adds is the eighth way of classifying vowels using [ATR] distinction.

For stops, Whiteley (1965) identifies them as: [p,t,k]. The IPA chart of Ekegusii stops would then be as in Tab. 1.1.

Table 1.1: IPA chart of of EkeGusii stop consonants

	Labials	**Alveolars**	**velars**
Plosives	p	t	k

According to Omoke (2012:12) and Onkwani (2011) EkeGusii consonant inventory does not include the nasal compounds or the clusters of the glide [ɰ] which co-occurs with the stops, a possible future study area.

Much of the work done by researchers on EkeGusii sounds touches only on phonology, which is the role of sounds in a language, while phonetics is based on the acoustic end (Hayward 2013).

The language was selected since the phonetics of the language has been understudied especially from the acoustics perspective. Whiteley (1965) identified the vowels and stops without describing their qualities; Bosire (1993) studied EkeGusii dialects; Cammenga (2002) describes phonology and morphology of the language; Mecha (2006) studied EkeGusii reduplication; Otieno (2013) analysed speech impairments. None of these studied the phonetics of EkeGusii more especially from acoustic phonetics perpective.

1.2 Statement of the Problem

Existing literature on EkeGusii sounds relied on subjective impressions. There is therefore need to provide a more reliable description of the speech sounds. This can be done by acoustic analysis of the sounds. Therefore, this study was geared towards a description of features or properties of the sounds of EkeGusii with focus on (a) vowels, (b) stops and (c) the effect of connected speech on vowels and stops based on data obtained from native speakers of the language. Moreover, there are several phonetic and distributional peculiarities about vowels and stops in any language that need to be defined clearly: remarkably, the vowel spaces, duration and the voice onset time which need to be defined through actual measurements. Vowel space and duration discriminate vowels either within the language or in comparison with other languages. Voice onset time is also an important quality to be measured for stop consonants since languages classify their stops largely based on voice onset time. Impressionistic description of such sound qualities is not complete for lack of being quantified. These qualities also define the various features distinguishing one vowel from another or one stop from another. To place the description of the language on a firm scientific footing, this thesis used the earlier works as a point of departure to quantify acoustically, the speech sounds of EkeGusii.

1.4 Objectives of the study

The general objective of the study is to supply a complete acoustic description of EkeGusii vowels /i e ɛ a ɔ o u/ and voiceless stops /p t k/. This descriptive study of EkeGusii sound system aims at the following;

1. To analyse the basic phonetic properties of EkeGusii vowels/i e ɛ a ɔ o u/, such as: F1, F2, F3, F0 and length.

2. To describe the acoustic properties of EkeGusii stops /p t k/, including such as: duration, voice onset time, burst intensity, fundamental frequency of vowel after stop consonant and F2 transitions and locus equations of vowels after stop consonants.
3. To analyse how the properties obtained from the citation data are affected by running speech.

1.5 Research questions

This study tries to answer the following research questions.

1. What are the acoustic properties of EkeGusii vowels?
2. What are the acoustic properties of EkeGusii stops?
3. How are the properties obtained from citation data affected by running speech?

1.6 Theoretical Framework

This study was guided by the Source-filter Theory an acoustic theory of speech production (Fant 1960) and as it has been discussed and adopted by different researchers focusing on both the sound source and the filter. Also, the discussion of the theory by Flanagan (1965), Fry (1979), Ladefoged (1996), and Johnson (2003) will supply more details for this study. In the source-filter theory, sound wave is generated at source, the air waves are modified by the air passages or tubes as the air particles rush out into the atmosphere creating the various sounds. Fant (1968) points out that the raw form of a sound is produced in the vocal tract. This raw sound is manipulated by the vocal tract and propagated in waves. These waves are manipulated in diverse ways to produce the various sounds in a language.

The source filter theory is appropriate for this research because it explains the production of vowels and stop consonants, the focus of this study. More importantly, as has been noted by other scholars, it makes it possible to track the effect of vocal fold manipulation and the resultant acoustic effects on the sounds (Shadle 1997), and the various articulatory gestures that go into the production of vowels and stops are described in a time sequence (Liberman 1977).

According to the Source-Filter Theory, (Fant 1960), sounds are produced the same way as the air in an organ pipe or bottle, that is, from the source of the sound wave, through the articulators that manipulate the sound wave variously and then out into the atmosphere as a unique recognizable sound in a language. The sound that we hear travels from the noise making source which are the vocal folds to the lips. The sound energy then radiates from the lips of the speaker to the ears of the listener for them to hear. Some of the sound energy is reflected back into the vocal tract. The addition of the reflected sound energy with the source energy tends to amplify energy at some frequencies and damp energy at others, depending on the length and shape of the vocal tract. This means that the vocal folds are the source of sound energy and the vocal tract is a frequency, altering the timbre of the vocal fold sound. This theory informs the way sounds can be seen to result from the vocal fold vibrations at different pitches and amplitudes which result in different timbres that we hear as different sounds. All human speech sounds are produced by the modulations of the vocal tubes.

Again, the Source-Filter Theory is suitable for a descriptive study as the present one since it sufficiently describes the idea that different vocal tracts have different resonant frequencies. The length of a resonating portion also differs substantially for different speech sounds. For vowels, the whole tract, from the glottis to the lips, serves as the acoustic filter for the noise generated by the vibrating vocal folds. In fricatives, the resonating portion of the vocal tract is shorter. Ladefoged and Johnson (2003) give an example of [s] where the portion of the vocal tract that serves as the acoustic filter is from the alveolar ridge to the lips. Hence, the lowest formant in [s] will have a much higher frequency than the F1 found in vowels. This explains why the fricative noises are so noticeable in the high-pass filtered utterances recorded in a spectrograph. This is unlike the glottal fricative [h] in which the whole vocal tract from the glottis to the lips is involved. This explains its low frequency.

Another factor that determines the frequencies of the resonant overtones is the shape of the vocal tract. The assumption has always been that the vocal tract has uniform diameter which is not always the case. In the production of nasals, for example, the main cavity is divided further into the sinus cavities as well as the oral cavity. This will obviously alter the perception of the sound thus produced. Stevens (1989) acknowledges that this theory is sufficient enough to provide the right theoretical explanation for the production of all speech sounds.

In closing, the Source Filter Theory gives a guide on how we can interpret the acoustic features and spectrographic shapes of the airwaves produced by the informants in their speech. However, some aspects like overlap and intra-speaker variability cannot be completely explained by this theory only that we can assume that the speaker aims at a certain peak of which the hearer picks and makes a phonological decision given the alternatives on offer from the language.

1.7 Justification of the study

Phonetic description is a fundamental component of a language documentation project. The present research is the first study that provides a complete acoustic description of Ekegusii vowels and voiceless stops. Speech acoustic analysis is important because it gives an avenue to researchers to make a phonetic description of a language. It is also a fact and data driven process within which a language is described and documented linguistically.

Many specialisms require knowledge of acoustic phonetics, from psychology, speech therapy and pronunciation training, to forensic linguistics. Increasingly today, interactive displays based on speech waveform analysis are being used as a precise tool in many areas like in the classroom by language teachers to assist in fine-tuning pronunciation of foreign learners of languages and also engineers who are concerned with speech processing applications like text-to-speech systems, speech recognition systems and dialog systems. In forensic phonetics, speech acoustic analysis is used for speaker identification.

Therefore, there is a need to provide acoustic analyses of Ekegusii vowel and stop consonant sounds as a way of documenting and revitalising Ekegusii language which faces serious challenge of being side lined in the face of other languages like Kiswahili and English. These analyses will hopefully provide the basis for future research on Ekegusii sound system. This study provides the basics for speech databases and online archiving for EkeGusii sound system. It also is a reference point for speech therapists who can now analyse a client's deviant speech from the norm provided here among other users.

1.8.1 Scope

The present work is an acoustic analysis of characteristics of 7 EkeGusii vowel sounds and 3 voiceless stop consonants. The sampling technique used was purposeful sampling. This choice informed by the speaker characteristics is not free from sampling errors since dialectal considerations are difficult to reckon as there are no such things as dialect boundaries. A future work that draws the dialectal map of EkeGusii may resolve this conundrum.

1.8.2 Limitations

The study is limited in that it did not subsume all EkeGusii speech sounds. The present study had content limitation as it was not possible to analyse all speech sounds in the language except for vowels and stop consonants. Concerning theory, the aspects of Source-Filter Theory that explain the production of other types of consonants apart from the stops were not considered.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter reviews existing literature on phonetic sounds in general and Ekegusii sounds in particular. It begins with a brief review of the literature on vowel production in general then followed by an overview of previous works on Ekegusii vowels. A review of stop consonants is made in general and on the existing literature in Ekegusii. Lastly, the vowel and stop consonant characteristics in running speech and the literature on acoustic analyses are presented.

2.1 Related literature on vowel production

Following the source-filter theory (Fant 1960) vowels are produced with the vocal fold vibration as the source and the vocal tract as filter. The modes of phonation determine the type of source signal in the production of any sound. Whenever we speak, Ladefoged and Disner (2012), we create a disturbance in the air around, a sound wave, which is a small but rapid variation in air pressure. All languages in the world use this air to produce their sounds. Crystal (2008) notes that a vowel sound is initiated by the vibrating larynx as air particles move out. Then, the various resonance chambers of the vocal tract, especially movements of the tongue and lips act on the laryngeal source to modify or filter the air so as to make sure that certain harmonics relative to others are reinforced. Thus are vowels produced by vibrating vocal folds, which means a quasi-periodic signal; whispered vowels are produced by a partially open and relaxed glottis which produces an aperiodic and noisy signal and breathy voice vowels are produced by the combination of the quasi-periodic and aperiodic vibration of the vocal folds. There are three aspects of sounds that can be distinguished: pitch, loudness and quality (Lodge 2009). This study quantifies these qualities in EkeGusii language.

The pitch of a sound depends on the rate of repetition of the sound wave. A short section of a sound wave of a vowel repeats itself every one-hundredth of a second. The frequency of repetition is 100 times a second that is, 100 H_z. The same vowel can be said with a higher frequency of say, 200 H_z, which means that it has a higher pitch.

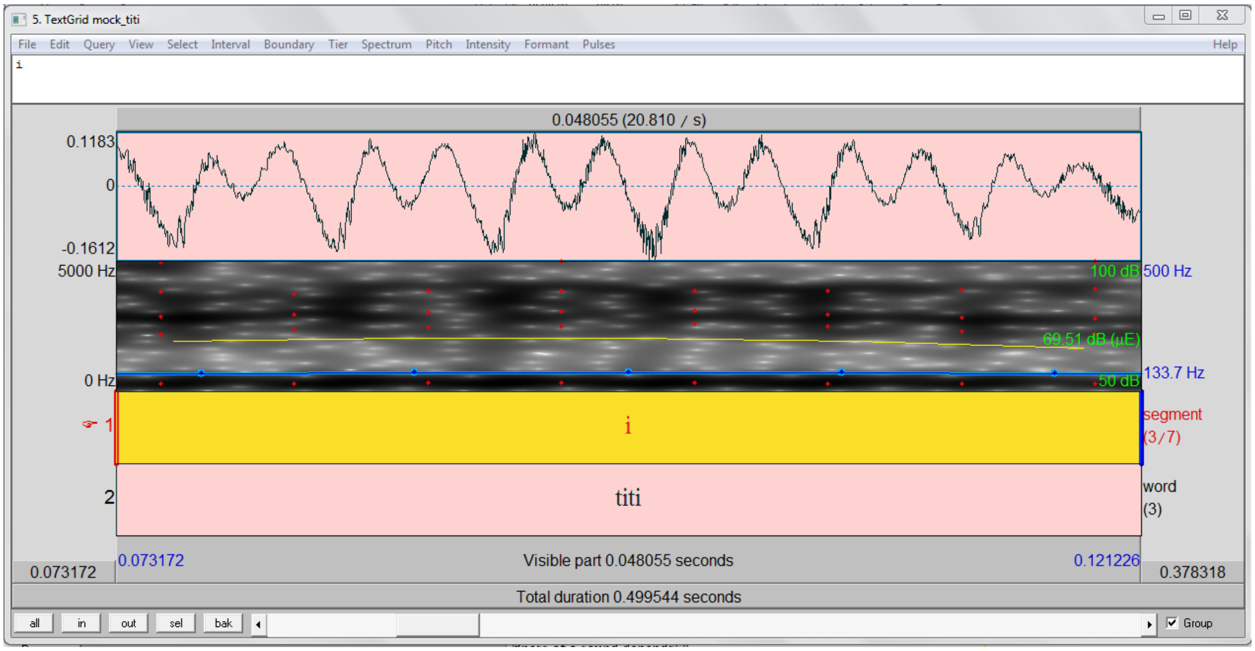


Figure 2.1: waveform and spectrogram of /i/

The pitch of /i/ in this mock recording can be seen in blue. This can be measured at the point where the vowel is seen as most stable, possibly in the middle. The best way to work with Praat software is to set the pitch logger for the sound file. This gives Praat a directory to locate the file and determine the pitch. It can be in terms of the mean pitch of the selected sound or a full listing of the pitch after every time interval.

The loudness of a sound depends on the size of the variation in air pressure (Ladefoged & Disner, 2012). This causes the sound waves to have amplitude. Differences in amplitude are measured in decibels (dB) as it can be seen from the mock recording above with a yellow line and the numbers automatically tracked and written in green at the right margin of the spectrograph.

Sounds also differ in quality, which is also called timbre. The differences in vowel quality have more complex acoustic correlates, loosely summed up as differences in the shape of the sound wave (Ladefoged 2002).

The vibration of vocal folds has different frequencies for different individuals and genders. In general, males have glottal vibration, that is, fundamental frequency that is considerably lower than that of females. Ladefoged (2001a) states that adult males have a fundamental frequency of 80-200 H_z whereas females have up to 400 H_z of fundamental frequency (F0). The F0 for children goes up to 500 H_z (Liberman 1977). This is because of the greater mass, length and tension of the focal folds. Males have long and massive vocal folds whereas females and children have shorter and less massive vocal folds. Smaller and less massive vocal cords are associated with a faster vibration of the vocal cords (Clark & Yallop, 1995). These findings are a pointer to the variations that result from sex and age of the informants for this study.

When the source wave passes through the vocal tract, energy of the source is damped at certain frequencies and amplified at other frequencies. Those frequencies at which maximum energy will pass through are referred to as center frequencies of the formants (Liberman 1977:30). For each vowel, the vocal tract takes different shapes and the frequencies at which energy is amplified and dampened, differ accordingly. As a result, each vowel has its characteristic set of formant center frequencies. The first three formants are very important to distinguish a vowel in question (Ladefoged 2001a, b). The center frequency of first formant (F1) relates to the height of the tongue and identifies whether vowels are high or low. The center frequency of the second formant (F2) is used to identify the frontness or backness of vowels but for back vowels, it also has information on lip rounding (Ladefoged 2001a, b). As a result, back vowels that are rounded have lower formants than those which are not. The center frequency of the third formant (F3) is used to identify the degree of lip rounding, that is, whether the vowel is round or not. F2 and F3 differ, the extent to which F3 show rounding is higher for front vowels than for back vowels (Ladefoged 2001b). Ekegusii has seven vowels, as shown above, evenly distributed between the front and back distinction, that is, three front vowels /i e ɛ/, three back vowels /ɔ o u/ and one low, central vowel /a/.

The formant center frequencies of a given vowel differ due to the size of the vocal tract of a speaker (Ladefoged 2001b, Rosner & Pickering 1994). If a speaker has a small vocal tract, his formant values will be higher. If a speaker has long vocal tract, his formant values will be smaller.

The explanation behind such a phenomenon is that a larger vocal tract holds a larger volume of air which vibrates faster (Ladefoged2001b). That is why children produce vowels which have higher formants than the vowels produced by females and females produce vowels which have higher formant values than those produced by male speakers.

Choi (1991) presented data showing that the type of vowel preceding and following consonants also has an effect in changing the formant frequency values. The assimilatory effects of the semivowels /j/ and /w/ lower F1, whereas uvular and pharyngeal consonants result in vowels having higher F1 due to their lowering effect. Therefore, the type of consonants surrounding the vowels determine directly how the vowels will present in their frequency values (Ladefoged & Maddieson, 1996).

Rosner & pickering (1994) also postulate that dialectal variations, such as sociolectal or regional, have effect on the values ascribed to vowels and sometimes these differences would be equal to those seen between two different languages. Ekegusii has dialectal variations (Mecha 2006, Bosire 1993) and this is bound to have a bearing on the sounds of Ekegusii language for this research.

Also, Lindblom & Sundberg (1971) conclude in their study that F1 increases as the jaw opening grows larger, and as the tongue approximates the pharyngeal cavity; F1 decreases as the tongue approximates the palate; F2 increases as the tongue approximates the palate, when the tongue shape is modified to create constrictions in the vocal tract, and when there is less rounding; F2 decreases as the tongue approximates the pharynx and when the vowel is rounded.

In the production of vowels, there is no significant obstruction of airstream in the vocal tract (Ladefoged 2001a). The description of vowels is based on the height of the body of the tongue, the part that rises above the normal rest position and the condition of the lips. Ladefoged and Johnson (2003) indicate that there are three main aspects of vowel quality. Vowel height which is inversely proportional to the frequency of the first formant; backness, which is proportional to the difference between the frequencies of the second and first formants; and the degree of lip rounding, which usually lowers both the second and third formants.

Vowels are also classed as front, central or back depending on the part of the tongue that rises above the normal position. Thus, traditional terms high versus low front versus back and rounded versus unrounded are most widely used parameters for most vowel systems of the languages of the world (Ladefoged & Maddieson 1996).

Chomsky & Halle (1968) also recognize four heights of vowels which are: high, high-mid, low-mid and low. That is the basis that Lindau (1978) in her summary of the features of vowels around the world used to conclude that the four vowel heights are enough to account for all contrasts in any given language. In contrast, the IPA (2005) representation of vowels gives us seven vowel heights. It is important to note that no one given language is able to utilize the seven distinct heights. Ladefoged and Maddieson (1996) suggest that there could be a maximum of five vowel heights in a language. Therefore, the only points of reference that have been a point of agreement over the ages in the study of vowels are vowel backness or frontness distinction; namely, front, central and back (Jekale 2011).

In more recent times, vowels are not only described according to their articulatory properties but also acoustically as the main thrust of this research. In acoustics, vowels are best identified by their formant center frequencies (Ladefoged & Maddieson, 1996; Ladefoged, 2000a, b; Ladefoged & Johnson, 2011; Ashby, 2011; Lodge 2009). In articulatory-to acoustic mapping of vowel features, different acoustic properties represent the height and backness of vowels. F1 center frequencies represent vowel height. This can also be represented by using the difference between F1 and F0 shown by Traunmuller (1981).

The front back distinction of vowels can be captured by the difference between F1 and F2 (F2-F1) (Ladefoged and Maddieson 1996). Many other phoneticians only use F2 instead of the difference of F1 and F2. Ladefoged (2001b) differs a bit in that he uses a non-linear (mel) scale of the F2 representation. When drawing the formant values on a chart, F1 is plotted on a vertical axis and F2 is plotted on the horizontal axis. Ladefoged and Disner (2012) note the origin of the plot is put at the top right of the graph so that when one goes from left to right and from bottom to top the F2 and F1 values decrease. They continue to say that one point that should be noted in the comparison of the IPA vowel chart and the F1-F2 plot is that the IPA vowel chart is produced as a reference and is based on equidistant classification of height and backness. The acoustic/auditory hapezoid is not based on equidistant classification of height and backness, but depends on actual formant values. In the end, a complete match is not expected between the articulatory and acoustic representations of the vowel system.

2.2 Previous studies on Ekegusii vowels.

A preacher was bidding farewell to a congregation and he chose to read from the Bible the book of second Corinthians, chapter thirteen verses eleven. Because he was not a native speaker of Ekegusii, he mispronounced a number of vowels and consonants to our amusement as the congregation. The problem sounds were /ɔ ɛ β ɣ/ but instead the speaker read them as /o e b g/ respectively. The text in Ekegusii orthography is quoted below in italics with the attending transcription below it:

Omoerio, abaminto, motigare buya. Mobe abaikeranu, moremigwe, mobe nomoyo

ɔmɔɛriɔ aβaminto motiɣarɛ βuja mɔβɛ aβaikeranu mɔrɛmiɣwe mɔβɛ nɔmɔjɔ

oyomo, momenye ase omorembe. Na Nyasae bw'obwanchani na bw'omorembe

ɔjɔmɔ mɔmɛɲɛ ase ɔmɔrɛmbɛ na ɲasae bwɔbwanʧani na bwɔmɔrɛmbɛ

abe amo nainwe.

aβɛ amɔ nainwe

(2 Corinthians 13:11)

Ekegusii orthography identifies only five vowels as /a e i o u/ making it hard to read without native instinct. The distinction between the mid-high and mid-low front vowels /e ɛ/ as well as the mid-high and mid-low back vowels /o ɔ/ are especially problematic owing to the [ATR] differences not marked orthogr

aphically. Whitely (1960) identified seven basic Gusii vowels. The works that followed on Ekegusii vowels (Guthrie 1967, Bosire 1993, Cammenga 2002, Mecha 2006 among others) point to the same number of vowels with a four height distinction as: high, mid-high, mid-low and low.

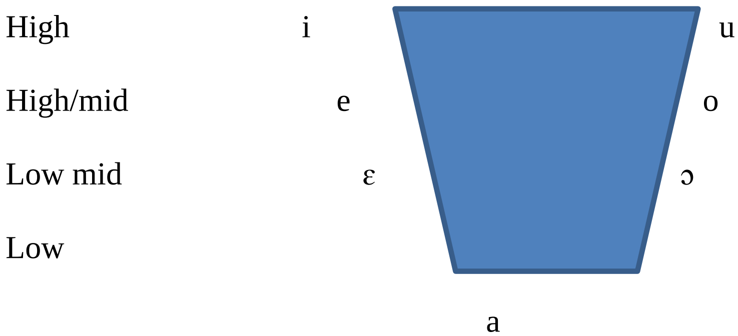


Figure 2.2: Whitely (1960) annotation of EkeGusii vowels

Cammenga (2002) agrees with Whiteley (1965) on the vowel height distinction but he also moves on to assert that Whitely (1965) does not define the phonetic or phonological significance of these symbols exactly. Cammenga (2002) goes ahead to give an Ekegusii vowel inventory where the vowel segments are differentiated in terms of minimally distinctive phonological features as in Fig. 2.3.

	i	e	ɛ	a	ɔ	o	u
High	+	+	-	-	-	+	+
Mid	-	+	+	-	+	+	-
Back	-	-	-	+	-	-	+
ATR	+	-	-	+	-	-	+

Figure 2.3: Cammenga (2002) annotation of EkeGusii vowels

For Cammenga (2002), advanced tongue Root [ATR] feature is distinctive in Ekegusii vowels. The vowels [i], [a] and [u] are specifically phonetically for [+ATR]. Onkwani (2011) adds that all vowels on the Ekegusii chart are produced with an open vocal tract. The changing shape, movement and position of the tongue determine their quality.

This research departs from the previous studies as seen above in that their description of vowels relied on impression and on traditional minimal pair approach while this study relies on acoustic features to describe the vowels. This thesis describes Ekegusii vowels in acoustic terms which, hitherto, have been described by scholars in articulatory terms. By so doing, this study will be creating the necessary link between articulation and acoustics in Ekegusii. This linkage is necessary because every "articulatory movement and posture has its own acoustic effects" (Lodge 2009).

2.2.1 Vowel chart

According to Davenport and Hannahs (2003) the dimensions of high vs. low front vs. back within the vowel space allow us to establish a limit to vowel articulation. They are of the view that the vowel chart does not represent an accurate anatomical diagram of vowel space, but an idealized version of it, based on perceptual rather than actual articulatory distances between the vowels. They argue that positions on the chart are not necessarily those for any particular language rather they indicate the limits of vowelness. The vowel points on the chart are just reference points against which specific language vowels can be indicated (Daniel Jones 1917). This means that English /i/ and EkeGusii /i/ may not necessarily occupy the same position, only that they are related.

However, the problem confronting every researcher concerns overlapping of vowels within the vowel spaces and also huge inter-speaker and intra-speaker variations. Ever since the introduction of the spectrograms in the 1940s, it became easier for researchers to visualize speech variability within and across speakers for the same sound or word. There are acoustic differences between male and male, males and females, children and adults and so on. These need to be explained acoustically since the auditory system is able to differentiate between them.

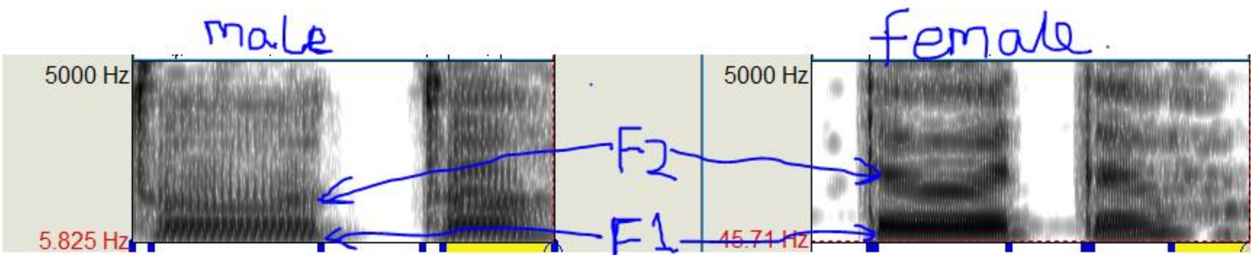


Figure 2.4 Spectrograms of a male (RM2) and a female (RM3) saying "toto." The first two formants for the first vowel /o/ are marked as F1 and F2.

Fig. 2.4 shows that vowel formants are shifted upwards for the female as compared to the male particularly for F2 but still the word is perceived as "toto." According to the model presented by Peterson and Barney (1952), the vowel productions from male, female and child talkers had considerable variability within each vowel space. That is the reason influencing modern phoneticians to use normalization procedures when comparing vowel spatial differences in different contexts or genders where the data is first normalized before comparison as initial Hz value of vowel formant frequency is not suitable for direct comparison.

Vowel normalization is a way of minimizing differences between vowels using mathematical algorithms while at the same time maintaining the qualities that separate the contexts and speakers. There are two kinds of vowel normalization procedures (vowel intrinsic or vowel extrinsic) depending on the type of information they employ (Nearey 1989). According to Adank (2004) normalization procedures are useful for sociolinguistic purposes. The problem with this kind of procedure is when it has to be applied to small group of informants such that it could be confusing whether the variations are caused by dialectal causes or just speaker-anatomical causes. Whatever the case, each procedure has its own pros and cons and it is just upon the researcher to weigh them. This study is informed by Adank's argument that the sociophonetic aim here is to transform acoustic representation that will minimize the acoustic consequences of anatomical speaker-related sources of variation while still preserving the phonemic and the sociolinguistic variation. According to Disner (1980), the reasons for carrying out a vowel normalization procedure are: (a) to eliminate variation caused by physiological differences among speakers (i.e., differences in mouth sizes), (b) to preserve sociolinguistic/dialectal/cross-linguistic differences in vowel quality, (c) to preserve phonological distinctions among vowels, and (d) to model the cognitive process that allow human listeners to normalize vowels uttered by different speakers. Since there are no acoustic studies on EkeGusii vowels, this was the first study of this nature.

Out of twelve normalization procedures proposed by different scholars, there are some that are deemed more effective than others. The purpose of normalization determines the choice one makes so as to suit a given project. The difficulty of choosing a normalization procedure led Adank, P., Smits, R., and van Hout, R. (2004) to compare the various normalization procedures for their efficacy in handling vowel data. The procedures were compared on how effectively they, (a) preserve phonemic information, (b) preserve information about the talkers' regional background (or sociolinguistic information), and (c) minimize anatomical/physiological variation in acoustic representations of vowels. They reported that procedures that use information across multiple vowels ('vowel-extrinsic' information) to normalize a single vowel token performed better than those that include only information contained in the vowel token itself ('vowel-intrinsic' information. Examples of vowel-extrinsic procedures are Gerstman (1968), Lobanov (1971), Nordstrom (1976), and Nearey (1978). Of these, Lobanov (1971) and Nearey (1978) performed best. More recently Fabricius, Watt and Johnson (2009) algorithm has also proved to be among the best. Based on the foregoing, this research adopted both Lobanov's and Fabricius, Watt and Johnson's models to normalize the vowel formants' data for all informants and for the groups.

2.2.2 Duration

Vowels can be differentiated in terms of quality, that is, height, backness and roundedness and also in terms of quantity (length). Davenport & Hannahs (2003) indicate that the quantity or length of vowels might not be phonemic in some languages but that "is not always the case for all languages." Whiteley (1965) gives Ekegusii vowel quantity distinction. However, the data he used are insufficient since the list he gives cannot pass as minimal pairs for example: *βɛːɾa* 'stay' against *βeɾa* 'boil'. Cammenga (2002:43) gives more accurate examples of vowel length distinctions. These foundational studies have yielded basic information on Ekegusii; however, it is important to further their utility in providing a description of the language by studying them instrumentally to give the language a more thorough description to supplement impressionistic descriptions.

Higgins (2012) studied Ikoma language in her dissertation with the goal of firmly establishing the seven vowel system and their lengthened contrastive counterparts. Her finding is important to this present research since Ikoma, the language she studied, is related to Ekegusii, the focus language of this thesis. The time taken to articulate a segment varies depending on the segment type and phonation. Among vowels, the parameter of hemp of tongue and duration could have a correlation. For example, *bana* /βana/ ‘prophesy’ and *kana* /kana/ ‘deny’ may have different durations and qualities for [a] just because of the initial consonant sound. In an acoustic study like this one, the duration of any segment can automatically be tracked and displayed. This makes it easy to just compare the durations of various segments under study.

The seven vowels in Ekegusii occur both as short and long vowels. As a result, Whitely (1965) suggests that length in Ekegusii vowels cause a change in meaning. Lehiste (1970) argues that duration perception is important. Apart from establishing whether differences in duration “constitute the basis of perceived differences,’ in this thesis, I will verify these observations by measuring vowels’ duration and establish their differences. Data involving minimal pairs would be used. Here, I will seek to measure this duration by describing such differences as in the following mock recording spoken by a 13-year-old female, comparing a minimal pair that only differs in the duration of the first vowel:

β**i**ɾi those ones (near) β**i:**ɾi those ones (far)

The visible part on Fig. 2.5 displays the lengths of the minimal pair for easy comparison of duration. This cannot be done in impressionistic studies like those cited here.

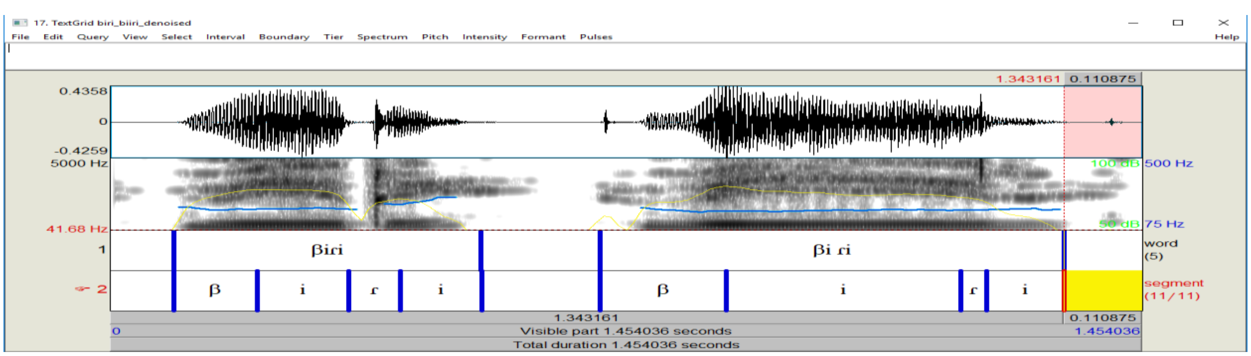


Figure 2.5: waveform and spectrogram of the minimal pair /βiɾi/ and /βi:ɾi/ by RM1

Fig. 2.4 exemplifies procedure for measuring duration. Using sound waves obtained from Praat, vowel length was determined from the first glottal pulse to vowel offset. The boundary markings above can tell how the short vowel sound /i/ differs from the long vowel sound /i:/ as much as the difference is contrastive in Ekegusii. this is unlike impressionistic studies done by Whiteley (1965) and others who cannot quantify the quantity of a segment.

2.3 Articulatory and acoustic characteristics of stops

Speech sounds are created by modifying the volume and direction of flow of air using various parts of the human respiratory system. For consonants, we have a number of sub-classes based on their manner of articulation. Davenport and Hannahs (2003) propose that the broad divisions in consonants are obstruents and sonorants. For obstruents, the airflow is noticeably restricted, with the articulators either in complete closure or close approximation. In sonorants, there is no such restriction in the oral tract, or nasal tract is open, either way, the air has free passage through the vocal tract. On the very basis of stricture, obstruents can further be divided into stops, fricatives and affricates. This study will focus on stop consonants found in Ekegusii. Stops are non-resonant consonant sounds involving the greatest degree of obstruction. They are characterized by a momentary cessation of airflow, that is, a complete closure in the oral tract, preventing the airflow from exiting through the mouth. They may be oral (velum raised) or nasal (velum lowered). Davenport and Hannahs (2005) add that pulmonic eggressive oral stops are often also known as plosives and, as expected for obstruents, are either voiced or voiceless. But nasal stops are sonorants and thus, in most cases, are voiced only in many languages of the world. Ekegusii language does not have nasal stops as per the existing literature on the language.

Generally speaking, all pulmonic eggressive oral stops involve three clearly identifiable stages. The first one is the closing stage, when the active articulation is raised to come into contact with the passive articulator. Then, there is the closure, the second stage. This is when the articulators remain in contact and the air builds up behind the blockage. The third stage is the release stage when the active articulator is lowered, allowing the air to be released with some force. While the closure is held, (Skandera & Burleign 2005), air pressure is build up and then the release of air comes explosively through the mouth.

An important distinction in stops deals with voicing. Plosives may either be voiced (produced with a narrowed glottis) or voiceless (produced with an open glottis). The voice distinction, Davenport & Hannahs (2005), gives us contrasts in words which can be well illustrated using minimal pairs like *latter* and *ladder* in English. In Ekegusii, however, only three stops are identified in the literature: /p/, /t/ and /k/ Cammenga (2002) and also in Whiteley's (1965) list of stops in the language. Of the three, /t/ and /k/ are very productive with so many words available in the Ekegusii. /p/ is not productive though many nativized loanwords from English and Kiswahili use this sound.

Stops have been studied extensively in many languages of the world. Extensive experimental studies have been conducted to identify the acoustic characteristics of stops and attempts have been made to identify acoustic cues that identify different places and manners of articulation among stops. However, the stops in Ekegusii have not been studied acoustically. Whiteley (1965), Cammenga (2002), and Mecha (2006) all list the various consonantal segments in Ekegusii including the stop consonants together with an impressionistic, articulatory description of each.

2.3.1 Durational measurement of stops

Part of the cues identifying various stop consonants is duration. There are different durational aspects that have to be measured. The first one is closure duration which is the duration of the consonant before burst or release. There are two explanations given for effect of place on closure duration. There is one that is connected with the pressure in the cavity behind the closure. Maddieson (1997) reports that larger cavity means longer time for pressure to build and reach equilibrium while smaller cavity means shorter time to build pressure and reach equilibrium. This suggests that stops produced in the front part of the mouth will have longer closure duration than those produced at the back of the mouth.

There is another factor that is consequential on closure duration, that is, compressibility of articulators. When the articulators involved in the closure are soft or tissue-like, there is a good deal of compression as they contact unlike alveolars which have a soft tissue contacting a hard surface. Contact with a hard surface results to a rapid rebound from ballistic movement that creates the contact (Maddieson 1997).

The closure of stops can result to a totally voiceless stop, partially voiced or totally voiced stop especially after vowels. Ekegusii syllable structure is CV, Cammenga (2002), meaning that every stop is followed by a vowel which is essentially voiced. In any case, the voiced part of the closure as well as the percentage of the voiced part of the closure to the total closure can be considered separately to identify stops into different categories. Using this acoustic cue, the question of whether we have /d/ instead of /t/ for the speakers of Maate dialect of Ekegusii can be settled.

The second durational aspect is voice onset time (VOT). This refers to the duration of the part of stop from release of the closure up to the onset of voicing or vibration of the vocal folds. Ashby

(2014) gives a sketch of a summary of VOT characteristics showing positive, zero and negative VOTs as seen below.

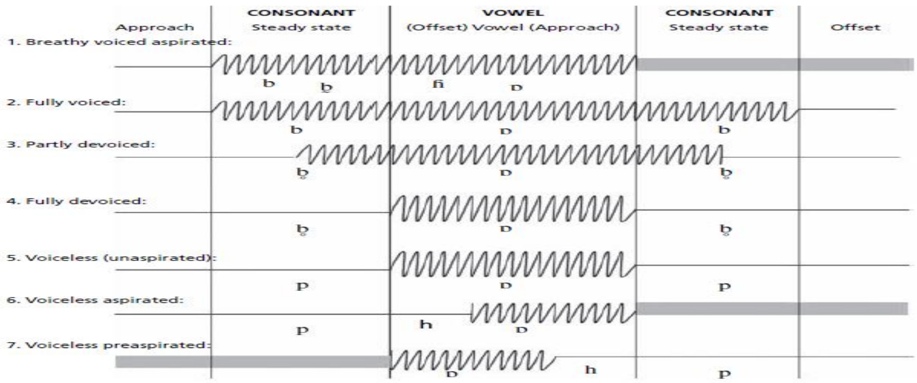


Figure 2.6: Schematic representations of degrees of (de)voicing adapted from Ashby (2014)

The norm for voiceless obstruents is represented above in line five which shows zero VOT. Here, vocal fold behaviour is indistinguishable from that associated with a fully devoiced lenis obstruent. The vocal fold only starts to vibrate simultaneously with the removal of the oral constriction, in this case, complete closure for the stops. Sounds displaying this pattern are said to be unaspirated.

Voiceless unaspirated stops like those found in Ekegusii, can be represented in a parametric diagram, aligning movement by the active articulator with activity of the vocal folds.

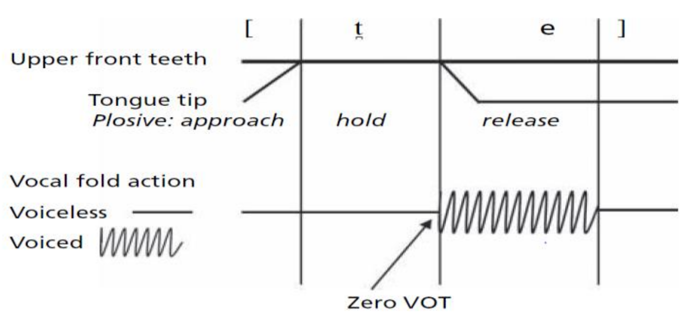


Figure 2.7: Parametric representation of vocal fold movement and action of the tongue tip in the pronunciation of French /te/ Ashby (2011).

If the voicelessness continues into the beginning of the following sonorant, after the removal of the consonantal constriction, there is a long or positive VOT. This is measurable in milliseconds to define the length of time it takes for voicing to begin. What happens here is that the vocal fold remains fully open, effectively devoicing the onset to any following sonorant. If the sonorant is a vowel, then we can hear what we describe as a /h/ sound or aspiration (Ashby 2011).

To measure VOT, the moment of burst in the stop has to be located in the speech waveform. That is how Pongprapunt (2012) measured the duration between the burst and the start of vocal fold vibration, which is marked by periodic sound waves. Of more interest to this study is what Jekale (2011) found out in Amharic stops that, the contrast of VOT values due to place of articulation is occasioned by several reasons. Yet still, the general trend is that VOT values increase as one is moving from front to the back in the oral cavity. Ren (1985) noted that this is because of the volume of the cavity behind the point of constriction. This means that a relatively smaller volume of the supralaryngeal cavity behind the closure for the velar stops causes a greater pressure, which will take longer to fall and allow an adequate transglottal pressure for the initiation of vocal folds' vibration (Cho & Ladefoged 1999).

Further, the volume of the cavity in front of the point of constriction affects the VOT values. The relatively greater mass of the contained air in front of velar stops, one of the three identified in EkeGusii by the literatures, causes a greater obstruction to the release of the pressure behind the velar stop, so that this pressure will take longer to fall, resulting in greater delay in producing an adequate transglottal pressure.

Again, the movement of the articulators has a bearing on the VOT values. A faster articulatory velocity like the movement of tongue dorsum or lower lip, allows a more rapid decrease in the pressure behind the closure and thus a shorter time before building up an appropriate transglottal pressure.

Also, the extent of articulatory contact area bears on VOT value. The more extended contact area in laminal, dental and velar stop results in a slower release because of the Bernoulli Effect pulling the articulators together. This happens since articulators come apart more slowly hence a longer time before an appropriate transglottal pressure is produced (Jekale 2012).

To add to the effects is change of glottal opening area. The glottal opening area after the release will decrease less rapidly for the velar than for the alveolar or labial stop since the internal pressure drops more slowly for the velar stop.

As Jekale (2012) notes that there is temporal adjustment between closure duration and voice onset time. There is a trade-off between the closure duration and the VOT so that there is a fixed duration of vocal fold opening. This study analysed and quantified these features giving clear demarcations and descriptions for each quality and for each speaker and group.

2.3.2 Burst spectral shape measurements

According to Fant (1960), stops have different special shapes based on the front cavity beyond the point of obstruction, and this means that the burst spectra gives us information on the size and shape of the vocal tract area in front of obstruction. Burst spectral shape differences have been used to identify place differences among stops in the same language as well as stops of different languages. Blumstein (1979) reported that velar, alveolar and labial stops have different spectral shapes in their research. This study analysed Ekegusii stops also after Blumstein's model. Forest (1988) presented a numerical way of expressing spectral shapes and identified four important measures of spectral mean frequency, spectral standard deviation, skewness and kurtosis. Spectral mean measures the average frequency on which energy is concentrated. Spectral standard deviation measures the spread of the frequency around the mean. Skewness measures to what extent the distribution is symmetrical. Kurtosis measures how peaked the spectrum is. Spectral shapes vary from language to language and this research established and documented how they are in EkeGusii.

Stoel-Gammon, Williams and Buder (1994) used the four measurements pointed out above to differentiate between alveolar and dental stops. Comparing American and Swedish stops, they found that American English stops had smaller standard deviations and higher kurtosis than Swedish stops, meaning that American stops had more compact and peaked spectra than Swedish stops. The same qualities were investigated and established in EkeGusii in this research.

2.3.3 Amplitude and intensity measurements

There are different types of amplitude and intensity measures that can be made to show the difference between different stops. The first one is burst amplitude/intensity. This is the amplitude/intensity of a stop relative to the following vowel. Keating, Westbury and Stevens (1980) reported that alveolar stops had an early amplitude peak at release of closure while the peak of velars occurred later in English. Because of the high subglottal pressure, this is twice that of pulmonic stops, ejective stops are described to have greater amplitude in the stop burst (Ladefoged & Maddieson 1996).

Secondly, it can be measured by relative burst amplitude/intensity. This refers to the amplitude/intensity of the stop burst relative to the amplitude of the following vowel. Jongman, Blumstein and Lahiri (1985) noted that alveolar stops had a louder burst than dental stops. Further, it is possible to use relative amplitude to differentiate inter- as well as intra- language differences between stops. They also noted that individual speakers showed differences in the number of tokens they identify as dentals or alveolars.

Again, there is an absolute dB rise from vowel onset to vowel maximum conducted on the vowel following a stop. It is the difference between the peak amplitude/intensity and the onset amplitude/intensity of the vowel after the stop. The peak considered for this type of study is the left-most peak, also called the local peak. Russel (1977) found out that in Mam, at dental and uvular places, absolute dB rise differentiated glottalic stops since they had large absolute dB rise than those following pulmonic stops.

2.3.4 Voice measurement

Voice/phonation measurements can be tracked using F0 and jitter measurements. F0 measurements of the following vowel after the stop has been found to be one of the acoustic cues differentiating voiceless from voiced stops and ejective from pulmonic stops. Two types of F0 studies have been used in the experimental investigation of stops.

One F0 measurement is the F0 at the vowel onset. Maddieson (1997) state that there is a universal tendency for F0 of vowels following voiceless stops to be higher than the F0 of vowels following voiced stops. Different factors are said to have combined effects of lowering F0 after voiced consonant and raising F0 after voiceless stops. Maddieson (1997) asserts that the playing of various organs during articulation, like the lowered larynx position, aerodynamic effects of a subglottal constriction, and devoicing strategies that involve the tensing of vocal folds, make sure that in no case F0 can be higher after a voiced stop than after a voiceless one.

Another interesting aspect under investigation in the present study is due to Wright, Hargus and Davis (2002) who reported that male and female speakers had different patterns of F0 values of vowels after stops. For males, the vowels had their F0 raised by 8Hz whereas for females, the vowels after ejectives had their F0 lowered by 22Hz.

Furthermore, F0 measurement can be done through F0 perturbation which is the difference between the onset and the middle F0 of the vowel following a stop. This measure is conducted to normalize individual differences.

Jitter is a voice measurement that shows how periodic the sound wave is. This is the average absolute difference between consecutive periods, divided by the average period. The most common jitter measurement is the local jitter that is usually expressed as percentage (Boersma & Weenink 2010). The local jitter is defined as the relative absolute second-order difference of the point. For modal voice the jitter is low, but for creaky voice the jitter becomes higher. Jitter can be measured at the onset of the vowel following a stop consonant. To normalize individual differences, jitter perturbation is measured as the difference between the jitter at the onset and the middle of the vowel following a stop consonant. Wright, Hargus and Davis (2002) and Ham (2007) have reported that in many languages, vowels preceded by voiceless unaspirated stops have been found to have lower jitter perturbation values.

2.3.5 Coarticulation

The origin of coarticulation studies can be traced back to Menzerath and Lacerda (1933) who popularized the term which over the years has come to mean instances where two successive sounds are articulated together. This is where we find a phonetic variation of a given sound due to its taking on some of the features of nearby sounds (Ohala, 1993).

Speech segments occur in a series and not in isolation. Volenec (2015) noted that neighbouring segments “exert a certain degree of influence of one phonetic structure on another.” In the study of phonetics, we may separate various segments but in natural speech, they are just part of continuous articulatory movements of concatenated string of sounds.

To analyse coarticulation in this study, the second formant frequency, F2, transition will be investigated. F2 transition correlates with place of articulation of consonants in that it varies with the neighbouring vowel. F2 frequency change and direction are difficult to attribute to a particular place of articulation since the degree of rise and fall depends on neighbouring vowels (Harrington, 2011). Locus equations can be used to measure coarticulatory influence of a vowel on a preceding plosive. What is aimed at here is vowel target that is least influenced by consonantal context and most similar to citation-form production of the same vowel. This is usually at vowel mid-point, the steadiest state part of the vowel where the vowel formants, and hence the phonetic quality, change minimally.

In many cases it has been observed that vowel targets could shift proportionally because of coarticulation. According to Agwuele, Sussman and Lindblom (2009) modified locus equations can also account for rate induced vowel reduction effects and as cues for predicting frequencies of F2 transition onsets in rapid speech.

Coarticulation can be represented statistically using schematic representation of locus equations. A locus equation is a presentation of a "straight-line regression fit to coordinates formed by plotting onsets of second formant (F2) transition in relation to their coarticulated F2 mid vowel 'target frequencies'" (Sussman, Hoemeke & Ahmed, 1993). Locus equations have been noted in the literatures as useful tools in the discrimination of place of articulation since they indicate degrees of coarticulation between stop consonants and the following vowel. The strongest degree of coarticulation is reported for bilabials then velars and the least degree of coarticulation with alveolars. In this study, I explored locus equations as a cue for place of articulation for EkeGusii plosives noting the degree of coarticulation for the three identified stop consonants.

2.4 Vowel and stop consonant qualities in running speech

Ladefoged and Disner (2012) note that running speech is very difficult to analyse since we do not just put vowels and consonants together as if they are stored up differently. Rather, speaking involves retrieving whole words as stored up in the brain of a native speaker. Words are stored up as wholes and then pulled out to be used appropriately. Speech is organised in such manner as perception is organised in terms of larger units like syllables or whole words.

Each vowel and stop in the combination has its unique temporal duration allowing it to be co-articulated with other sounds in the series as dictated by first, the phonotactics in operation in the language, and second, the physiological make of the speech tubes of the speaker.

The effect of running speech on the quality of vowels and stops can be reflected in terms of duration, change of place and manner of articulation, spectral shape measurements and voice measurements. For the vowels, F1 and F2 are commonly used in phonetic and phonological research as an objective measure of vowel quality.

The segments identified above can be observed only as aspects of syllables. For descriptive purposes, a syllable is divided into its onset and rhyme. The rhyming part of the syllable consists of the vowel and any consonants that come after it. Any consonant before the rhyme form the onset. The rhyme of a syllable can be further divided into nucleus, the vocalic part, and the coda, any final consonant.

Languages differ significantly in their syllable structure. Cammenga (2002) notes that Ekegusii does not have a coda after the nucleus since every syllable end in a vowel. For the two constituents, the nucleus is obligatory while the onset is optional. When in other languages like English the nucleus must not always be a vowel (Davenport & Hannahs 2005), in Ekegusii the nucleus must be a vowel. Mtenje (1980) writes that the syllable structure of most Bantu languages is “the canonical CV.” Consonant clusters may be permitted but they are subject to some ‘phonotactic constraints’. Cammenga (2002) discusses the syllable in Ekegusii from three perspectives. First, the syllable must contain at least a nucleus. This nucleus may or may not branch, and typically dominates [-cons] segments. If it does not branch, it may not dominate either two distinct vowels or one long vowel. Second, the coda, which is empty, is considered as a projection of the nucleus and so is the syllable node. Third, the syllable may not branch, and typically dominates a [+cons] segment glide (which is interpreted as a high vowel dominated by the syllable node).

Syllabification is assumed to apply at the level of the prosodic word. Properties of the typical syllable may change in the course of the derivation. Associated with syllable structure are such prosodic features as stress and tone which are beyond the scope of the present research. Within a phonological word, primary stress is normally assigned to the penultimate syllable. Ashby (2012) presents the idea of acoustic cues which are the means by which we recognize sounds.

Research done on English has reported that the fortis and lenis consonant distinction affects the duration of preceding vowel segment in the nucleus or coda of the same syllable. Fortis consonants clip these, shortening their duration when compared with the norm allophone. Indeed, Sonorant duration thus constitutes an acoustic cue. Apart from duration, we also rely on VOT, that is, the time taken to establish vocal fold vibration in the following sound, rather than intrinsic differences in the silent hold-phases. Therefore, acoustic cues are essentially phonetic features. They are embodied in our phonetic transcription of what we have heard. Vowels affect the acoustic, articulation and perceptual features of stops that they occur with. Johnson (2003) reports that velar stop [k] often changes to palatal affricate [tʃ] where the following vowel is [i]. This palatalization is reported in Slavic, Indo-Iranian, Salish, English, Mayan, Chinese and Bantu. It will be interesting to subject the same claims to Ekegusii data and analyse the results. According to Guion (1998) the palatalization can be explained, in that, [k] is fronted in anticipation of the front vowel [i]. Other front vowels like [e] and [æ] have been reported to condition such changes in many languages. Guion (1998) demonstrates that palatalization has articulatory motivation by use of confusion matrices. Guion demonstrates that there exists confusion in running speech among [k], [g], [tʃ] and [ʤ] as produced by American English speakers.

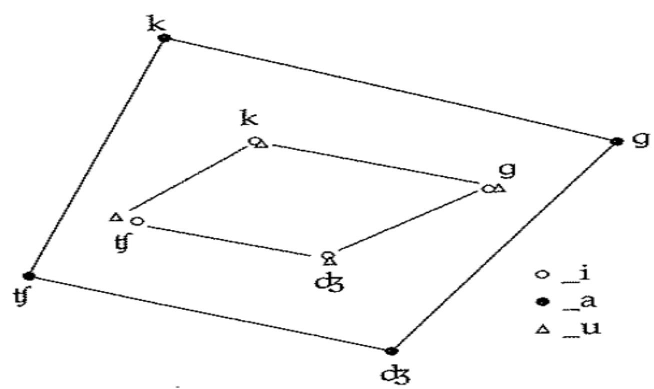


Figure 2.8: Confusion matrices of perceptual maps of [k], [g], [tʃ] and [ʤ] in different vowel contexts (Guion 1998).

The perceptual space is organized so that the velar stops are at the top and the palato-alveolar affricates are at the bottom. The horizontal dimension has the voiceless consonants on the right. These consonants were much easier for listeners to identify when the following vowel was [a]. Johnson (2003) concludes that what the above observation mean is that the reduced perceptual distance between [k] and [tʃ] in the [i] environment means that listeners may be less likely to notice when a speaker produces [tʃ] instead of [k] in this environment. Articulatory motivation still holds – [i] exert fronting pressure. But we still have a perceptual 'licensing' effect, so that the [k] to [tʃ] change is permitted in [i] environment because this change is not likely to be very noticeable.

2.5 Speech sounds perception

Perception of speech sounds is important to this research since listeners experience auditory objects, and not acoustic records like waveforms or spectrograms. To this regard, it is important to consider the basic properties of auditory perception as they relate to speech acoustics, Johnson (2003), and how such signals become meaningful to both speaker and listener.

The anatomy of the peripheral system is made such that it translates acoustic signals into neural signals. In the course of translation, it also performs amplitude compression and a kind of Fourier analysis of the acoustic signal breaking it down into separate frequency components (Johnson 2003). This is done by the auditory system imposing a type of automatic volume control via amplitude compression, and so, it is responsive to a remarkable range of sound intensities (Moore 1982). Therefore, there is no one-to-one correspondence in frequency between acoustic and perceptual tracking of sound. Auditory sounds are shaped by the non-linearity of the auditory system.

By changing the parameters of synthesis, we may accordingly evaluate the perceptual importance of various speech-wave parameters. Fant (2004) notes that one observation to be made is that moderate changes of formants and bandwidths do not significantly change the vowel quality except under the most sensitive conditions, that is, when a sound is located at the boundary between two response categories. If the resulting impression is meaningful then it is worthy being investigated.

The auditory system acts as a filter of the acoustic signal through frequency selection. Frequency selectivity refers to the ability to resolve the sinusoidal components in a complex sound (Hardcastle, Laver & Gibbon, 2010). It plays a role in many aspects of auditory perception, including the perception of loudness, pitch and timbre which are important aspects of an acoustic analysis of speech. Fletcher (1940) suggested that frequency selectivity can be modelled by considering the peripheral auditory system as a bank of band-pass filters, with over-lapping pass bands. According to Fletcher (1940), the basilar membrane within the cochlea provided the basis for auditory filters. Each location on the basilar membrane responds to a limited range of frequencies, so each different point corresponds to a filter with a different centre frequency. These different ranges of frequencies of sound are easily tracked by an automatic tracking computer application such as Praat. Nimz (2015) asserts that the listeners part is to perceive these ranges and make meaning out of them; making a differentiation between different types of cues in sound perception, for example, spectral (quality dimension) and durational (quantity) cues, both of which are used to make meaning in EkeGusii.

Many speech sounds, however, are complex and consist of a combination of different sinusoidal waves with different frequencies (Lang, 2009). The lowest of them, the fundamental frequency, is perceived as pitch, whereas the others contribute to the timbre of a sound. The perception of the timbre of a sound is independent of its loudness and pitch. It is the energy distribution of different frequencies of a sound that determine perception of timbre.

Lang (2009) indicates that psychoacoustic experiments concerned with the sensation of loudness show that humans can perceive a remarkable range of sound intensities. This research will attempt to give a complete description of the various changing patterns of Ekegusii Vowels and Stops in terms of intensity and pitch and the contrastive result if any.

2.6 Acoustic analysis

Acoustic analysis has increasingly become an important tool at the disposal of linguists to substantiate their claims in a scientific way. It is a necessary tool across all fields of linguistics ranging from phonology, sociolinguistics to psycholinguistics.

This work addresses itself to basic descriptions of Ekegusii sounds. These include the waveform, the pitch curve, the intensity curve, the spectrogram, and formants. The work points out that each of the measures has many uses in the analysis of language depending on what the researcher aims at. The most common is the waveform which is a direct visualization of the recorded sound into a computer and it represents air pressure as a function of time (Boersma & Weenink, 2017). The waveform visually displays silences, nature of the sounds and time each one takes. Apart from that, many acoustic properties can be inferred from it like periodicity, intensity and spectral qualities.

This work gave a practical guide on how a researcher can measure acoustic properties of speech signals by hand when the number of sounds to be measured are limited and also if datasets are much larger, acoustic analyses can be automated by annotating landmarks in the acoustic signal and using ‘scripts’ in the analysis software to extract the needed acoustic measures.

To better analyse stop consonants, Locus Equations (LE) was adopted as cue for place of articulation in relationship to following vowel. According to Everett (2008) locus equations are linear regressions based on F2 formant transitions from vowel onsets to vowel midpoints. Normally the F2 value of vowel onset is plotted on the y-axis while the F2 value of vowel midpoint is plotted on the x-axis. When these numerous F2 onsets-F2 midpoint plots are plotted a locus equation is generated. Since Ekegusii is a CV language, each stop consonant is associated with a particular ensuing vowel with F2 onset and F2 midpoint transitions. This study utilized locus equation as a tool for linguistic analysis of Ekegusii sound system. Locus equations revealed coarticulation patterns that exist in EkeGusii CV patterns.

Locus Equations, according to Lindblom, Agwuele, Sussman and Cotes (2007), work best when applied to stop consonants since in the process of producing a stop-consonant sequence, the tongue must transition from a static position maintained momentarily during closure phase or stop gap and move to the position needed for the following vowel. This movement results into changing values of F2 from vowel onset to point of vowel maximal of F2 midpoint.

Locus equations are interpreted considering y-intercept and slope of the trend-line. Higher locus equation slopes of around 1.0 are indicative of greater CV coarticulation. The correlation between steepness of the slope and coarticulation is that steeper locus equation slopes are directly proportional to the similarity between F2 onset values and F2 midpoint values. This means that if F2 onset values and F2 midpoint values were nearly the same in all cases for the vowels following a stop consonant, the slope of the locus equation would be 1.0 and the y-intercept would be zero.

Locus Equations are characterized by slopes and y-intercept values. High slopes characterize stops with high degree of coarticulation because of F2 onsets and F2 midpoint values are quite similar as this implies proximity of tongue position at vowel midpoint. On the other hand, if the locus equation characterizing a given stop is not steep, it implies a greater difference between F2 onset and F2 midpoint values. Such a difference is indicative of a less malleable place of articulation for the stop in relation to the following vowel (Cole, Choi and Kim 2002).

Further, Krull (1987; 1989) used locus equations to quantify coarticulation effects on CV syllables. In her study, she showed that labial consonant loci undergo coarticulatory effects than dental consonant loci and that coarticulation is larger in spontaneous speech than words in citation form. The present study borrows her ideas about the coarticulatory effects on Ekegusii CV (read: stop-vowel) sequence and the effect of coarticulation on citation data as compared to data from carrier sentences.

According to Reetz-Jongman (2009) the equation corresponds to a linear function as:

$$F2\ (onset) = k\ F2\ (middle) + C$$

Where k is the slope and C is the intercept of the regression line. The more that a consonant is influenced by a vowel, the less the formant transitions converge to a common locus and the greater the slope in the plane of vowel onset frequency by vowel target frequency. For this reason, I used locus equations here as indicators of degree of coarticulation between stop consonants /p/, /t/ and /k/ and a following vowel.

2.7 Acoustic analysis

It has been noted through the literature presented here that EkeGusii phonetics has been understudied. The few works that deal with EkeGusii sounds were on phonology and they relied upon impressionistic description of the language. All the works cited here on acoustic phonetics were done for other languages especially European languages but none of them was in EkeGusii. Considering that acoustic description gives more depth and precision in describing sounds of a language by measuring and quantifying various qualities for vowels and stop consonants. This is the gap that existed in the literature that this study attempted to fill.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This section describes the procedure that was implemented in order to achieve the objectives of the study. It provides an explanation on the research design, the study area, and sampling procedures that were adopted. It then presents the tools of data collection and the methods of data analysis.

3.1 Research Design

This is a descriptive study of EkeGusii speech sounds that is aimed at providing an evidence based characterization of the vowels and stop consonants of EkeGusii. As such, it includes quantitative analyses since it quantifies the features of vowels along several dimensions such as vowel space and pitch. The features of stops such as stop duration and voice onset time are also quantified, as well as the way these qualities of stops and vowels are affected by running speech.

According to Ruane (2005) descriptive studies give a true picture of any phenomenon, setting, experience or group. For that reason, this research integrated both quantitative and qualitative approaches in the description of Ekegusii vowels and stop consonants. A mixed approach like this in a language documentation project such as the present study is important since each highlights reality in a different yet complementary way (Lazaraton 2005).

In the analysis of Ekegusii vowels and stops, the acoustic cues that have quantitative elements include: (1) sound duration, measured in seconds; (2) vowel formant frequencies, measured in Hertz (Hz); (3) sound intensity or amplitude, measured in decibels (dB). Also, (4) statistical values of the mean, (5) standard deviation (SD), (6) analysis of variance (ANOVA), and (7) discriminant analysis were used in the quantitative analysis. These procedures are explained in section 3.8 below.

To complement quantitative analyses, qualitative analyses were made in the form of figures, spectrograms and waveforms of the various sound segments under analysis. Some of these charts and figures are drawn from the quantitative data.

3.2 Variables

Mackey and Gass (2005) define variables as characteristics that vary from person to person, text to text and object to object. Acoustic characteristics from group means (males, females and children) are used here as independent variables while the acoustic realization of Ekegusii sounds are the dependent variables.

In this research, (1) sex, (2) age and (3) dialect are the moderator variables which Mackey and Gass (2005:103) described as characteristics of individuals or of treatment variables that may result in an interaction between an independent variable and other variables. The variation attributed to sex was mitigated by half of the sampled informants as female, and the other half as male. To properly account for the variation attributed to dialect, half of the sampled subjects were speakers of Maate dialect and the other half spoke Rogoro dialect of EkeGusii. For those variations attributable to age, I occasioned that four out of the twelve informants be children all aged eight years old, four adult females and four adult males. The data from the three groups namely: adult males, adult females and children were presented separately to avoid any distortion or mix-up whatsoever.

3.3 Location of the study

This study is based in Gusii land, that is, Kisii and Nyamira counties of the republic of Kenya. Kisii and Nyamira Counties are located to South-West of Kenya. The majority of the people here use EkeGusii in their day-to-day social interactions. Bosire (1993) divides the area into two: the south where they speak Ekemaate dialect and Northern part where they speak Ekerogoro dialect of EkeGusii. Omoke (2012) noted that Ekerogoro dialect is taken as the standard variety with majority of speakers while Ekemaate dialect. To determine the informants sampled from these places see discussion in section 3.5 below.

3.4 Target population

Kisii and Nyamira Counties has a population of 1.87 million according to National Census Report (2019). EkeGusii language is not just spoken in Kisii and Nyamira counties of Kenya but elsewhere in the country and even in Europe and America due to migration of the Gusii people. Those that live outside Gusii land are not part of the target population.

3.5 Sample and sampling techniques

3.5.1 Selection of the language

Ekegusii was selected on the basis that it is still widely under-studied in different aspects of language and especially, to the best of my knowledge, no acoustic phonetic study has ever been done on the language. The selection is also based on easy accessibility owing to the fact that I am a native speaker of EkeGusii language. The language is also facing a threat from the more dominant Kiswahili and English with the younger generation shunning their native language. All these reasons require that the language be properly described and documented.

3.5.2 Sample

This study purposively sampled twelve subjects from both Rogoro and Maate dialects of Ekegusii language (Bosire 1993) from the total population of 1.87 million. The subjects selected were native speakers of the language who grew up speaking the language at least until they started formal education where other languages (Kiswahili and English) are introduced. Another inclusion criterion was that the informants were those without any speech impairment whatsoever.

Three males and three females are enough for this kind of study (Ladefoged, 2003; Ladefoged & Disner, 2012). For this study, four females (MW1 aged 40, MW2 aged 25 and RW3 aged 20 and RW4 aged 38), four adult males (RM1 aged 42, RM2 aged 21 and MM3 aged 23 and MM4 aged 36) and four children (two boys and two girls all aged 8 years) were selected which is well above the bare minimums of three females and three males on the number of subjects for a study such as the present one. Therefore, 12 informants were selected, that is, three more informants above the minimum required of nine. The ages also varied since for adult informants there is no criterion for age except that informants are adults of above 18 years. For children, the age was 8 years, at which point ta child has mastered the language and secondary sex characteristics have not set in which affect speech, so as to control any intervening variables that could be age related (Ladefoged & Disner, 2012).

This study employed the model attributed to Milroy and Gordon (2003) of network sampling which is a type of purposive sampling. The researcher used the native speaker instinct to select individuals based on age, sex and dialect. To get access to the informants for consideration as possible informants, I made community contacts by proceeding from initial contacts to their friends, to the friends of this friend and so on, capitalizing on a natural ‘snowball’ effect (Schilling 2013).

For dialectal differences, I purposively picked two subjects from each group (males, females and children) to represent each of the two dialects of Ekegusii as mentioned above. This was done by mapping out the study area into zones for Rogoro and Maate dialect speakers. The Maate dialect of Ekegusii is an obvious minority exclusively spoken in South Mogirango and part of Bomachoge Chache constituencies. Being a native speaker, I am able to tell the difference hence speakers were chosen appropriately. The subjects were therefore picked based on their location and dialect. The subjects reported no language or hearing impairment and each was willing to participate in the study as an ethical consideration.

3.5.3 Instruments of data collection

3.5.2.1 Stimuli

I designed two lists after Ladefoged (2002): a) words in citation form bearing the target vowels and stop consonants and, b) carrier sentences with words having the target vowels and stop consonants. See the full list of words in citation form and carrier sentences on appendix 1. Tab. 3.1 and 3.2 are sample representatives for the conditions.

Table 3.1: List of minimal pairs used in the analysis of EkeGusii vowels in the /tvt/ context alternating short and long vowels

Orthography	**Transcription**	**gloss**
titi	**ti**ti	very (black)
tiiti	**ti:**ti	carry a baby on the back
teta	**te**ta	name of a place
teeta	te:ta	let it not pass
teta	**tɛ**ta	have sex
t**ee**ta	t**ɛ:**ta	have sex for long/repeatedly
tata	**ta**ta	father
taata	**ta:**ta	(calling) father
toti	**tɔ**ti	make soft
tooti	**tɔ:**ti	let us warm/make one to bask
t**o**to	t**o**to	non-word
t**oo**to	t**o:**to	calling 'Toto'
tuti	**tu**ti	name of a place/clan
tuutia	**tu:**tia	a variant of the place/clan name 'Tuti'

Table 3.2: Carrier sentences to be used in the analysis of Ekegusii vowels with highlighted target words.

Sentence	**Transcription**	**Gloss**
Teba **titi** tari **tiiti**	teβa **titi** taɾi **tiiti**	Say titi and not tiiti
Teba o**tete** tari **oteete**	tɛβa o**tete** taɾi **oteete**	say Otete not oteete
Tera buna ma**tete** tiga kobee**teeta**	tɛɾa βuna ma**tɛtɛ** tiɣa kɔβɛɛ**tɛ:ta**	Sing like Matete don't go into a discord
rora **tata taata** esani	ɾɔɾa **tata taata** esani	See that dad does not break the plate
O**toti** ake **toototi pi**	ɔ**tɔti** ake **tɔ:tɔti** pi	Make the ugali soft
O**toto** neyo**tooto**	o**toto** nejo**to:to**	Ototo is good for you
tututi ya sungu**tuuta**	**tutu**ti ja suŋgu**tu:ta**	Nonsensical tongue twister

Each informant was presented with the list of words and sentences in Ekegusii orthography. The list of words for eliciting vowel sounds and stop consonants was made by the researcher in the /tVt/ context. This context was used for both the word lists and target words in carrier sentences. On very few instances, a word in the context was not available and so a nonsense (non-word) word was coined so as to ensure that all the sounds analysed were in the same /tVt/ context (Otieno, 2013).

The words selected in word lists, both real and nonsense words, were those that form minimal pairs in order to control, as much as possible, any intervening variable like place of articulation and manner of articulation for stop consonants and lip rounding or height for vowels. Tab. 3.3 is a sample of words for collecting data on vowels.

Table 3.3: List of minimal pairs used in the analysis of Ekegusii stop consonants

Orthography	**Transcription**	**gloss**
titi	**ti**ti	very (black)
tata	**ta**ta	father
pipi	pipi	completely
papa	papa	very hard
popo	popo	ideophone
iki	iki	bring down
aka	aka	paint
oko	oko	this one

Only the vowels in the first syllable and the middle vowel could be measured. The final vowel could not be measured because of resonances at the end that make the vowel look longer than it really is.

Three tokens for each word per informant were extracted into a separate sound file and TextGrid. On the edit window, target non-empty categories for vowels or stop consonants were extracted and listed. These were the ones analysed and their averages calculated. Fig. 3.1 is a sample TextGrid as produced by RM1.

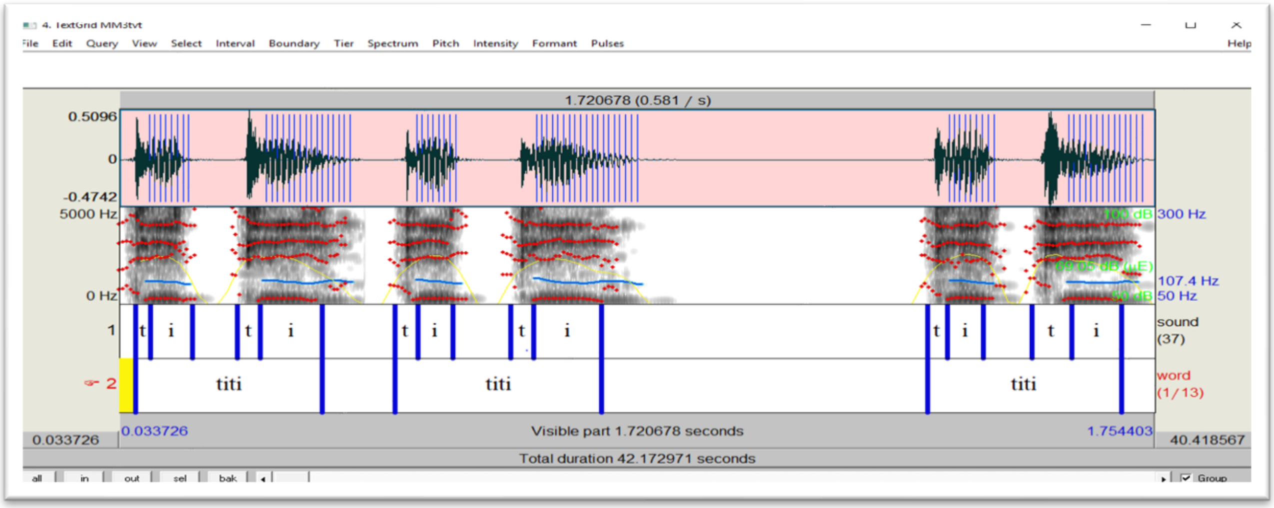


Figure 3.1: A sample of three repetitions of /titi/ produced by subject MM3

Tab. 3.1 gives the sample taken from MM3 of the word *titi* with three repetitions. The measurement for each target was thus taken and averages and other measures of dispersion taken and averaged for each subject then for the group.

3.6 Data collection

3.6.1 Recording

All the recording was made in the language laboratory at Kisii University. The lab is not attenuated. So, there was ambient noise among other noises from the environment. Efforts were made to control the noise. Each subject sits on a chair facing a computer screen with the headphone attached to the microphone adjusted. The recording was made with a Weile WL-906 microphone and the subjects spoke directly into the computer, the recordings were saved to the hard drive of the PC, using Windows 7, at a sampling rate of 44100 Hz.

The word list and sentences were prepared in EkeGusii orthography so that the subjects had no difficulty reading them. Before making the recording, each subject was given time to practice. Whenever a problem arose, the recording was repeated. This occurred mainly with [+_ATR] vowels since Ekegusii orthography does not make distinction between them except that the subject understands appropriate pronunciation from the context by employing their native speaker's instinct.

The recording was done after Jongman, A., Sereno, J., Wayland, R., and Wong, S. (1998) with the microphone connected to the computer, running on the Praat software, placed 10-15cm from the mouth and inclining at approximately 45 degrees from the side of the mouth. This is done to avoid the direct turbulence of air gushing out of the oral cavity as this can distort the recording. The informants were made to speak words three times and the recording stored as a sound file in Praat with a back-up on external memory. The gathering of these data took a period of three months. If any mistake was detected, the informant was asked to redo the recording.

3.7 Validity and reliability

Validity in research means that an instrument measures what it is supposed to measure. Mackey and Gass (2005) stated that this is done so as to enable the research make correct generalizations based on results from a particular measure. For a research to be reliable there ought to be precision in collection, coding and analysis of data. Such kind of data is seen as consistent and stable.

To ensure that this study was valid and reliable, the data were elicited from informants carefully selected for their unimpaired speech, un-affected by any accent which usually results from staying away from the immediate community using the language for a protracted period of time.

Such a determination was made by chatting with the informant about the places they have lived in. This study also made use of two talker selectors who were not part of the sample themselves. The talker selectors helped the researcher to ascertain that the Ekegusii spoken by the informant was unaffected by language impairment or having any foreign accent.

To further ensure validity and reliability of the data, the same word list and carrier sentences were used by all informants. This ensured that the same target sounds, in the same phonetic environment, were under analysis as elicited by all the subjects sampled for this study.

Often, the acoustic data will have differences or variations depending on the speakers. There is a gender difference to contend with since males and females have varying formant realizations because of their different physiology. Also, age produces variations as children produce higher formants than adults. To deal with these variations, this research employed normalization procedures using NORM, a resource freely available online. Adank, P., Smits, R., and van Hout, R. (2004) analysed the various procedures available and concluded that the algorithms proposed by Lobanov (1971) and Nearey (1978) were the best overall in normalizing data. There is another one not captured by Adank, P., Smits, R., & van Hout, R. (2004) proposed by Fabricius, Watt and Johnson (2009) which also has proved to be very effective in dealing with variations in vowel data.

3.8 Methods of data analysis

In this section, this study offers a description on how EkeGusii vowels and stop consonants were transcribed and analysed.

3.8.1 Description and analysis of Ekegusii vowels

Ekegusii monophthongs were identified in the literatures mentioned earlier as /a e ɛ a ɔ o u/. For each of the vowels, a word in the /tVt/ context was given and this formed the lexical identity to correspond with the vowel appearing with it. According to Melchers and Shaw (2011) such a lexical identity make use of key words 'intended to be unmistakable, no matter what accent one says them in'. Thus, TITI represents the vowel /i/ as TATA represent the vowel /a/. In this study, seven lexical items were tailored to correspond to the seven monophthongs in Ekegusii. Since the vowels in Ekegusii appear in the literatures to be in long and short forms, minimal pairs were used with the difference being only the length of the first vowel sound in a bisyllabic word (Cf. Appendix 1). Tab. 3.4 is a sample of minimal pairs to describe length.

Table 3.4: Sample of words in the /tvt/ context alternating short and long vowels

Orthography	**Transcription**	**gloss**
toti	**tɔ**ti	make soft
tooti	**tɔ:**ti	let us warm/make one to bask
t**o**to	t**o**to	non-word

As observed by Ladefoged and Disner (2012), a number of acoustic cues give guide on identification and description of vowel sounds on spectrograms and waveforms. The vowel segments have higher amplitudes since they are articulated with an open vocal tract. They are seen to be darker on the spectrogram because of their high intensity. The procedure for describing vowels was basically in terms of duration and formant frequencies. Duration is automatically mapped out on Praat after annotating the sound files as seen below on Tab. 3.2a and b.

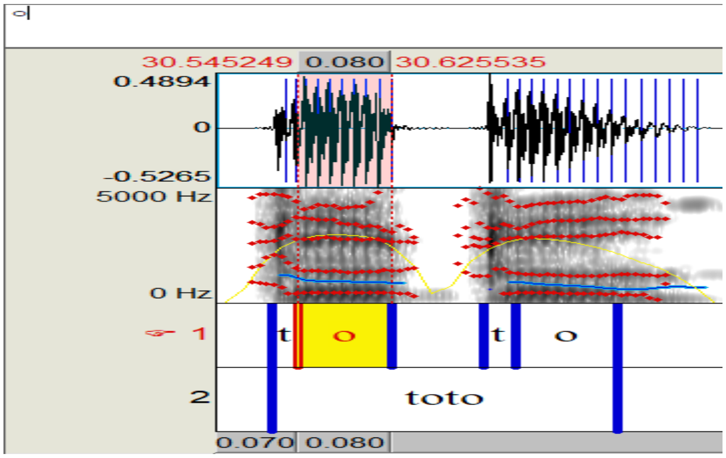


Figure 3.2a:A sample of the short vowel /o/ with automatic duration as produced by subject MM3

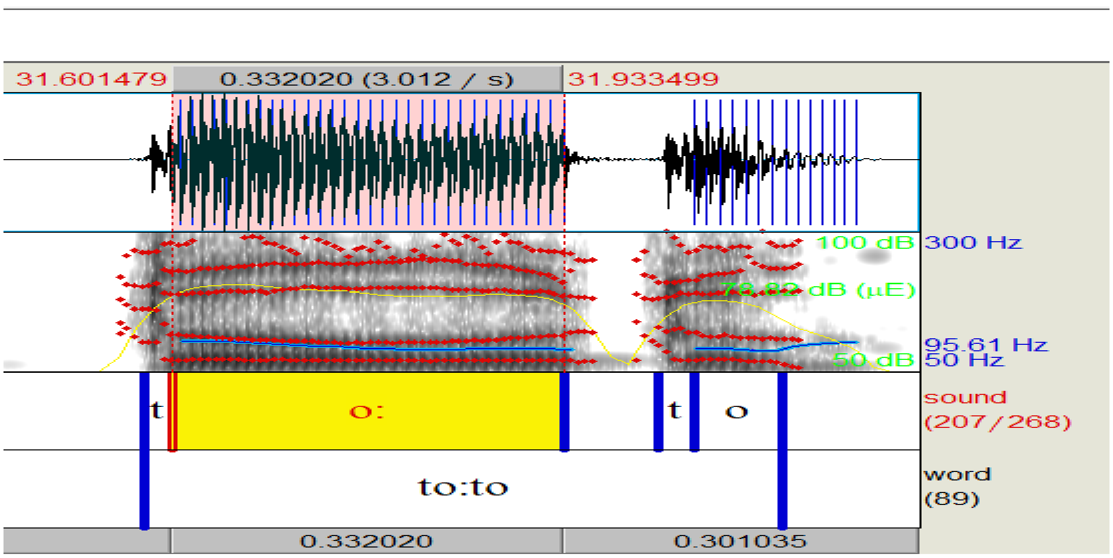


Figure 3.2b: A sample of the long vowel /o/ with automatic duration as produced by subject MM3

Fig. 3.2a and b show the duration of the vowels: the short vowel is 80 milliseconds in a, and 332 milliseconds in b. To work on larger data, the object window gives an option of querying the highlighted sound file to get a text file listing duration of segment and the first three formants which are copied to Excel spreadsheets for analysis.

After duration, the first two formants are crucial since F1 denotes vowel height and F2 denotes backness and also gives cue of roundedness of a vowel sound. The lower the formant value for F2, the back the vowel is. F3 is also associated with vowel roundedness. To draw these results for large sound files as these, a Praat script log file was created to generate the values for the first three formants for each vowel in the sound files.

An accurate representation of vowels according to Ladefoged and Disner (2012) requires relative value of formants. This is made possible by calculating the mean, that is, the sum of all scores divided by the number of observations. In order to take care of the variations between speakers, and even within the speaker, normalization of vowel data was done after Lobanov (1971) and Fabricius, Watt and Johnson (2009). The mean values for each sound segment under analysis, standard deviation and normalized values form the quantitative data for this research. Qualitative data for vowel sounds is represented in charts and figures of waveforms and spectrograms.

The data recorded for analysis of vowels was downsampled to 11025 Hz with the CSL 4400 software and analyzed with Praat version 6.0.32 by Boersma & Weenink (2017). F0, F1, F2 and F3 were extracted at the middle of the vowel manually using Praat as seen on Fig. 3.3.

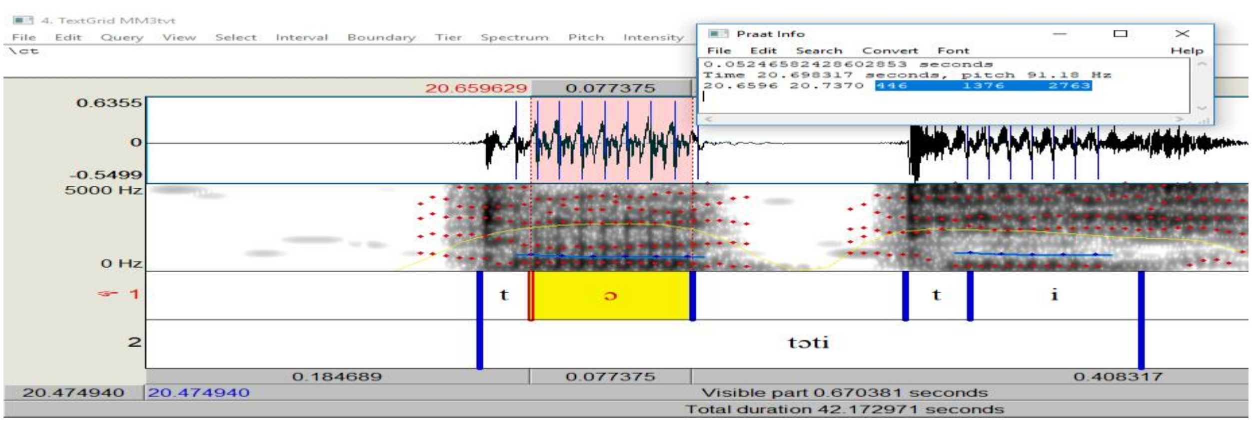


Figure 3.3: A sample of the long vowel /ɔ/ with automatic duration as produced by subject MM3 with text file for duration, pitch and F1, F2, F3.

Fig. 3.3 shows the highlighted vowel /ɔ/ duration and pitch as well as F1, F2 and F3 in blue in that order. These values are the ones copied for analysis.

For males, 0.01 seconds of window length and 0.01 time steps, maximum frequency 5000Hz with the Burg method (Anderson 1978 and Press et al 1992). For females, 0.01 seconds of window length and 0.01 time steps, maximum frequency 5500 Hz with the Burg method. F0 was extracted at the middle of the vowel with the auto-correction method recommended for intonation (Boersma & Weenink 2017). F0, F1, F2 and F3 for each vowel and each token were automatically generated through a log script that generates a report in a text file which was exported to the Excel work-book and SPSS analyser for statistical analyses.

To be able to do this, down-sampled speech signals were analysed with the Burg method with the stated parameters and the result extracted in a text. The formant values of the signal closest to the middle point were recorded on a spread sheet for further statistical analysis. This was followed by spectral analysis done using computer software by centering a 20ms hamming window at the middle of the vowel. An FFT analysis with 256 points was conducted to get the spectral shape of each vowel.

To measure duration, the onset of voicing was chosen as indication of the beginning of the vowel and the end of voicing as shown by the stability of vertical striations was chosen as its end. This is shown in Fig. 3.4.

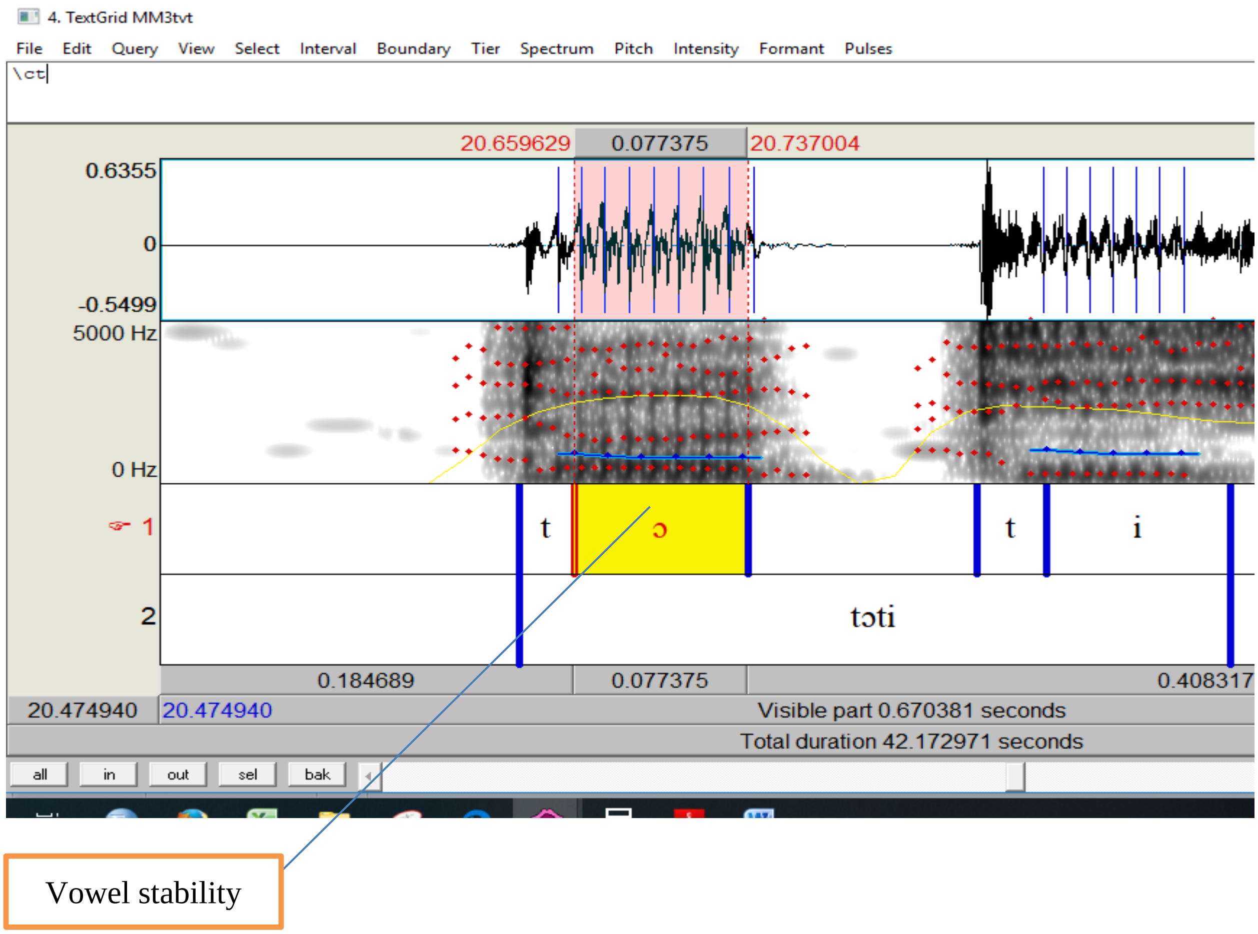


Figure 3.4: A sample of the long vowel /ɔ/ marked from the point of stability

Once the boundaries were located, the duration was recorded in milliseconds by taking the first three decimal places on the Praat window used in the durational measurement. Each vowel was measured three times in each of the contexts for the males, females and children.

The process of extracting these durations for each vowel and for each token can be a daunting and painfully slow process. The use of Praat duration logger has made it easy for those analysing large sound files, like those for this study.

3.8.2 Describing Ekegusii stop consonants.

As noted earlier from the literatures, Ekegusii has three voiceless stop consonants /p t k/ (Guthrie 1967). Three repetitions were elicited from each informant for each stop consonant. In total, 324 tokens were examined for the plosives. The cues that were used for the description of stop consonants include: (a) segment duration, (b) occlusion duration, (c) voice onset time, (d) burst duration, (e) F0 of vowel after the stop consonant, f) F2 onset and F2 mid-point transitions and (g) voice report.

Voice measurement was made using Praat. F0 was measured at the onset of the vowel marked by the steady state of the second formant and/or the start of the regular wave and pulse mark, and at the middle of the vowel taking a 30 milliseconds hamming window each. To enhance the measurement for voice, correlation method was used as recommended by the authors (Boersma & Weenink 2010). F0 perturbation was calculated by subtracting the middle F0 value from the onset F0 values of the vowels following the stop.

The plosives data were also examined using locus equations out of second formant transitions. The data were from the word list and those from carrier sentences. These were resampled to 11025 Hz using LPC. F2 onset values were extracted manually from within the first 50 milliseconds of vowel onset, that is, the first full cycle of a sound wave after the first glottal pulse. F2 mid values were taken at the point in the middle of the vowel following a stop consonant where the vowel formant is most stable. These two measurements were the ones plotted to come up with slopes, y-intercepts and regression equations.

3.9 Statistical data analysis

The various acoustic measurements that form the quantitative data for this research like duration, formants, fundamental frequency, voice onset time, voice reports and occlusions were recorded in Excel spread sheets and were statistically examined to compute (i) measures of dispersion, (ii) variance, and (iii) correlation. The mean and standard deviation of the different groups based on gender, age, position, place and voicing were calculated. To check whether the group results could be confirmed by individual results, individual results were computed. To check whether there are significant differences between the means of different variables and groups, a paired sample T-test (vowel duration in different contexts) and univariate analysis of variance were conducted.

The basis for carrying out a T-test was to look for any significant difference between the two various sets of data. T-test eliminates any bias during the analysis of data and in conclusion, it tells us whether the sets of data are significantly different or not. In this research, there are three groups of informants, males, females and children. What this entails are the questions whether the data are significantly different or it is just random and that there is no much difference after all. A value that is smaller than the critical value sought, for example $p < 0.05$, means that there was a less than five percent chance that the data set are random but greater than ninety-five percent chance that the data were significantly different. If, on the other hand, the p-value was greater than five percent ($p > 0.05$), the meaning is a five percent chance that the data is random and less than ninety-five percent confidence that the data set were truly significant. So when calculating this T-test, we need to see whether it is greater or less than the critical value because that will indicate the probability that the data sets were just random and there was no significance. In any set of data that we are using, we want as much confidence as possible hence a very small p-value to show that the data are not random but significantly different.

Whenever there was a need to see the contribution of variables and groups in statistically significant differences, Scheffe post-hoc test was used. Discriminant analysis was performed for both vowels and stops. Discriminant analyses involving three or more variables were conducted using the step-wise method and discriminant analyses involving one or two variables were conducted by entering all independents together. To normalize the results, a Lobanov (1971) transformation (z-transformation) was used. Adank (2003:2) notes that normalization procedures are useful when handling sociolinguistic data. A problem arises when it has to be applied to a small group of informants such that it would be confusing to ascertain whether the variations are caused by dialectal differences or just speaker-anatomical differences. Whatever the case, each procedure has its own pros and cons that every researcher has to contend with and pick the one that best suits the type of data being handled. Adank argues that the aim of normalization of sociophonetic data is to transform acoustic representation to minimize the acoustic consequences of anatomical speaker related sources of variation while still preserving the phonemic and sociolinguistic variation. The discriminant analysis used in this study was appropriate since the independents were entered together and dependent variables like formants, quantity and intensity were at interval level. The assumptions of discriminant analysis according to Garson (2012) are:

1. The observations are a random sample
2. Each predictor variable is normally distributed
3. Each of the response options for the dependent categories in the initial classification is correctly classified.
4. There must be at least two groups or categories, with each case belonging to only one group so that the groups are mutually exclusive and collectively exhaustive, that is, all cases can be placed in a group.
5. The groups or categories should be defined before collecting data.

The purposes of carrying out discriminant analysis according to Garson (2012) include:

1. To classify cases into groups using a discriminant prediction equation.
2. To test theory by observing whether cases are classified as predicted.

3. To investigate differences between or among groups.
4. To determine the most parsimonious way to distinguish among the groups.
5. To determine the percentage of variance in the dependent variable explained by the independents.
6. To determine the percentage of variance in the dependent variable explained by independents over and above the variance accounted for by control variables, using sequential discriminant analysis.
7. To assess relative importance of the independent variables in classifying the dependent variable.
8. To discard variables which are little related to group distinctions.
9. To infer the meaning of multiple discriminant analysis dimensions which distinguish groups based on discriminant loadings.

3.10 Locus equation analysis

The locus equation data were based on recordings from the 12 informants for this study, four adult males, four adult females and four (eight year olds) children. In order to derive locus equations, F2 measurements were taken at two points, that is, at F2 onset of vowel following a stop consonant and at F2 midpoint of the vowel. F2 onset was measured within 0-20 ms after the beginning of the vowel onset, specifically at the second glottal pulse where a clear F2 is discernable both on waveform and spectrogram. The second reading was taken at F2 midpoint, where F2 is seen as most stable, typically 60-100 ms after the point at which the first measurement was taken (Everett 2008).

3.11 Summary

In this chapter, it has been stated that this study adopted a descriptive research design which was both quantitative and qualitative. This chapter also elaborated on the tools and procedures that were used to collect oral data from the informants sampled for this study. The quantitative and qualitative data from all tokens were described. Quantitative data regards formant frequencies, fundamental frequency, segment duration, closure duration, and voice onset time.

CHAPTER FOUR

DATA PRESENTATION, ANALYSIS AND RESULTS

4.0 Introduction

In this chapter are presented results of recorded data, interpretations and explanations of the new insights gained from laboratory research. The first part will describe Ekegusii vowel sounds under: vowel formants and fundamental frequency, vowel chart, lip rounding and duration. The second part describes same vowel qualities as affected by running speech. After that, this study analyses Ekegusii stops under: stop consonant total duration, stop closure duration and voice onset time in citation form first and secondly how the same qualities are affected by running speech.

4.1 Ekegusii vowel sounds

A formal inquiry into Ekegusii sound system notes a common speakers' perception that the language has five vowels. This is evidenced from the traditional Roman orthographic system used in the language. The five vowels are [a e i o u]. There is a possibility that this was much influenced by the phonetics of Swahili, a dominant lingua-franca used in East and Central Africa (Hoffmann, 2011). However, spoken Ekegusii language reveals two more vowel sounds that are rightly represented using IPA vowel symbols convention as [ɛ, ɔ].

Carrier sentences (given in Appendix 5) and word lists (given in Appendix 1-4) generated data on each of the Ekegusii vowels. The formant values and the fundamental frequency (F0) for each of the vowels were extracted and listed for analysis on Excel spread sheets and SPSS. A total of 252 tokens for vowels were analysed for all the informants: four children (all aged eight years), four adult females and four adult males whose ages range from 20-42 years.

4.1.1 Ekegusii vowel formants and fundamental frequency results

Formants for each of the Ekegusii vowels were extracted using the query function on the object window. This was done after annotating the sound files and separating target vowels where tier one listed the separate segments and tier two listed whole words. This is exemplified in Fig. 4.1.

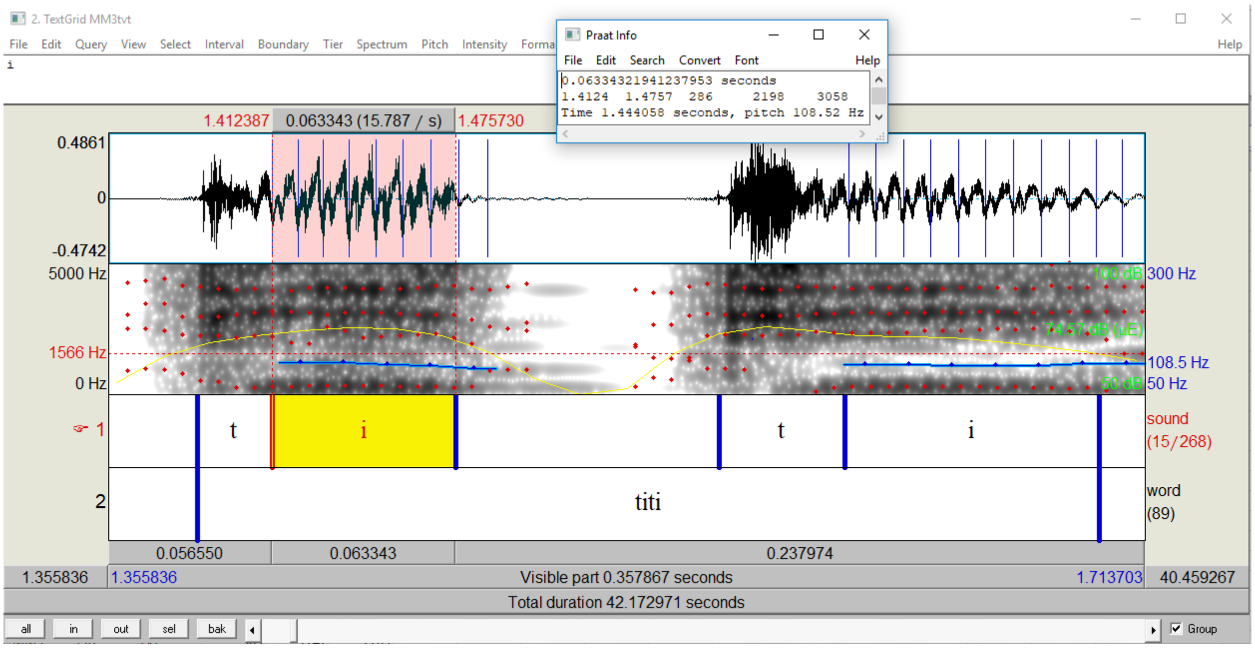


Figure 4.1: Vowel /i/ by MM3 with a text file listing pitch (F0), duration, F1, F2 and F3

The text file generated after querying the highlighted segment was copied and exported to MS-Excel spreadsheets for analysis. This was done for the three repetitions of each sound analysed then the mean was calculated for the subject and then the group of males.

Below are the target vowel formants from citation data for both real and nonsense words for the males, females, children and the mean values for individual subjects and groups.

4.1.1.1 Vowel formant and fundamental frequency results for males

Tab. 4.1 gives the averages for males for the fundamental frequency (F0), F1, F2 and F3 together with their respective standard deviations (hence SD).

Table 4.1 Vowel formant mean and SD for males

Vowel	F0	F0/sD	F1	F1/SD	F2	F2/SD	F3	F3/SD
i	**130**	35	**309**	59	**2148**	155	**2789**	368
e	**127**	22	**384**	37	**1988**	180	**2588**	308
ɛ	**120**	29	**481**	10	**1829**	150	**2658**	248
a	**112**	21	**619**	83	**1443**	186	**2564**	313
ɔ	**113**	25	**525**	40	**1253**	80	**2419**	257
o	**121**	23	**460**	53	**1173**	141	**2455**	226
u	**122**	27	**333**	33	**1253**	332	**2293**	284

The results in Tab. 4.1 for /i/ showed an F0 average of 130 Hz and standard deviation of 35. The SD for /i/ shows that the F0 mean for males was evenly spread out around the mean to the right or left of the mean among the informants. The vowel also had the biggest difference between F1 and F2; it had the lowest F1 mean value and the largest F2 value. The low SD indicates that there was no big difference between the values recorded for the four male informants.

For the vowel sound /e/, the mean value for F0 was 127 Hz and an SD of 22. At 384 Hz and an SD of 37, the F1 values were also close together for the males. F2 values for /e/ for males had a mean of 1988 Hz and an SD of 180. The standard Deviation is still on the lower side indicative that the difference between the four males was not statistically significant.

Generally, the results for the males showed the least values for all the vowel measurements made. This was as expected from the literature (Ladefoged & Disner, 2012) owing to the physiological composition of the adult male vocal tract. Front high vowel /i/ has a low F1 and the highest F2 and an equally high F3 while the central low vowel /a/ had the highest F1. The back vowels had low F2 to suggest the lip rounding gesture which lowers F2 unlike the front vowels with high F2 as compared to the front vowels.

Significance test (t-test) carried to test statistical difference between dialects of Ekegusii vowels as produced by adult males showed that each was different from the other significantly with $p<.05$. The differences in t-test scores ranged from 0.002 to 0.004 which can be translated statistically that the data had from 96 percent to 98 percent confidence rates higher than the threshold needed to reject the null hypothesis that there is no difference between the compared variables.

4.1.1.2 Vowel results for females

While the pitch (F0) will vary from speaker to speaker, the value for F1, F2 and F3 can be predicted. The front vowel /i/ will have a low F1 and a high F2. The vowel /u/, on the other hand, will have a low F1 and a low F2. The low central vowel /a/ will have a high F1 and a mid F2 value for the frequencies. Tab. 4.2 shows the results for females, that is, the formant frequencies, fundamental frequency and the standard deviations for each.

Table 4.2 Vowel formant mean and SD for females

Vowel sound	F0	SD of F0	F1	SD of F1	F2	SD of F2	F3	SD of F3
i	228	32	408	39	2235	322	3035	326
e	222	36	482	57	1968	270	2912	333
ɛ	207	22	522	21	1968	163	2962	278
a	204	18	680	68	1745	65	2829	438
ɔ	204	22	542	32	1540	178	2800	406
o	208	31	470	62	1384	110	2835	352
u	216	18	366	53	1418	97	2726	116

Ekegusii vowel sound /i/ for female informants has an F0 mean of 228 Hz and a small SD of 32. /i/ also has the lowest F1 of 408 Hz with an SD of 39 and the highest F2 of 2235 Hz with an SD of 322. It is the most fronted vowel as it surpasses /u/ which is lower at 366 Hz (the lower the F1 the higher it is placed on the vowel chart) for the first formant.

The vowel sound /e/ for the females had an F0 mean of 222 Hz with a low SD of 36 and a statistic range of 85 for the four entries. F1 mean was 482 Hz with an SD of 57 and an F2 of 1968 Hz with an SD of 270. While F0 and F1 were positively skewed to the right of the mean score, F2 was negatively skewed (-0.546) to the left of the mean score.

The vowel /ɛ/ had values very close to /e/ in many instances of overlap which is evident on the positioning of the two vowels on the chart as we shall see later. It had an F0 mean of 207 Hz with an SD of 22. The mean for F1 was 522 with an SD of 21 Hz and an F2 of 1968 Hz with an

SD of 163. The third formant (F3) had a mean of 2962 Hz and an SD of 278. F3 had the greatest variance owing to the large range of 611. It was also negatively skewed with -0.017 behind the mean.

The central vowel /a/ had an F0 mean of 204 Hz with a standard deviation of 18. F1 was 680 Hz with an SD of 69. F2 and F3 were 1745 Hz and 2829 Hz with SD of 65 and 438 respectively. All the mean values for this sound were positively skewed.

The back vowel /ɔ/ had an F0 of 204 Hz with an SD of 22and a mean range 47. The mean F1 was 542 Hz with an SD of 32. F2 mean was 1540 Hz and 178 for SD. F3 recorded a mean of 2800 Hz and an SD of 406. For this vowel sound, only the second formant was negatively skewed (-1.56) with a statistic mean range of 69.

The vowel sound /o/ for the females had an F0 mean of 208 Hz, a range of 67 and an SD of 32. F1 was at 470 Hz with an SD of 62, F2 had a mean of 1384 Hz with an SD of 110. The large SD is indicative of a huge statistic range. F3 had a mean of 2835 with a big SD of 352 with a range of 814.

The last vowel /u/ recorded an F0 mean of 216 Hz with an SD of 18. F1 was at 366 Hz and the SD was 53. F2 average for the females was 1418 Hz and the SD was at 97. F3 was also recorded a mean of 2726 Hz with an SD of 116. FO, F1 and F2 were negatively skewed with -0.8, -0.9 and -0.5 respectively.

The T-tests carried on the mean values for each vowel showed a confidence rate of between 96-99% which was above the statistical standard of 95% for confidence rates.

The data above indicates that the F0 values were very close for the females with no significant difference between them. The mean F0 for the females was about twice those of males which as since males have a longer and thicker vocal tract. Averages for all the formants were higher, as expected, to those of the males.

F1 and F2 values for the males are very close together as seen by very small SDs. The females' values differ significantly as seen by the greater SDs and $p<0.05$.

4.1.1.3 Vowel results for children

The formant frequencies for children are expected to be higher than those of females and males due to their shorter and less thick vocal apparatus. This is seen in Tab. 4.3.

Table 4.3 Vowel formant and fundamental frequency mean and SD for children

Vowel sound	F0	F0SD	F1	F1 SD	F2	F2 SD	F3	F3 SD
i	**280**	88	**392**	64	**2390**	446	**3428**	269
e	**284**	82	**460**	24	**2235**	447	**3256**	488
ɛ	**297**	68	**594**	71	**2156**	414	**3389**	470
a	**263**	60	**594**	357	**1535**	213	**2256**	586
ɔ	**267**	52	**628**	49	**1295**	38	**2943**	718
o	**341**	59	**489**	66	**1365**	101	**3233**	135
u	**256**	51	**399**	69	**1331**	138	**2867**	206

The vowel /i/ for children had an F0 mean of 280 Hz with a range of 191 and an SD of 88. This means that there was a big parity between the four children informants. The vowel also had recorded an F1 mean of 392 Hz, a range of 153 and an SD of 64 which meant that there was no great deviation from the mean. The second formant had a mean of 2390 Hz, a range of 971 and an SD of 446 Hz. The big standard deviation and range indicate a big difference among the individual scores. Lastly, the third formant recorded a mean of 3428 Hz, a range 624 and an SD of 269. The range also indicates a great dispersion of the figures from the four informants around the mean. Apart from F0, which was positively skewed, the other formant values were negatively skewed as seen too by the big variance for each of the formants.

The vowel /e/ for the children had an F0 mean of 284 Hz, a range of 183 and an SD of 82. F0 recorded a positive skewness of 1.7 meaning that the majority of the four entries were over and above the statistic mean. The first formant had a mean of 460 Hz, a range of 24 and an SD of 53. The small range and SD values mean that there was no big difference for the values of the four informants. F2 had a mean of 2235 Hz, a range of 898 and an SD of 447. F3 had a mean of 3256 Hz, a range of 1097 and an SD of 488. The results indicate a bigger rift between the four entries. F0 and F1 were positively skewed while F2 and F3 were negatively skewed.

The vowel sound /ɛ/ had an F0 mean of 297 Hz, a range of 154 and an SD of 68. F1 had a mean of 594 Hz, a range of 198 and an SD of 71. F2 had a mean of 2156 Hz, a range of 858 and an SD of 414. F3 had a mean of 3389 Hz, a range of 1097 and an SD of 470. Except for F0, which was positively skewed, F1, F2, and F3 were all negatively skewed.

The vowel sound /a/ had an F0 mean of 263 Hz, a range of 131 and an SD of 60. Just like the other F0 entries above, this too was positively skewed. F1 recorded 597 Hz, a range of 837 and an SD 357. F2 had a mean of 1535, a range of 484 and an SD of 213. F3 had 2255 Hz, a range of 1245 and an SD of 585 indicative of a great variation among the four entries.

The back vowel /ɔ/ had an F0 mean of 267, a range of 116 and an SD of 52. F0 shows a small variation among the four entries. F1 had a mean of 628 Hz, a range of 111 and an SD of 49. This was also negligible variation of individual scores from the statistic mean. F2 had a mean of 1295 Hz, a range of 79 and an SD of 38; all of the scores indicated very close values for all the four informants. F3 had a mean of 2943 Hz, a range of 1493 and an SD of 718. The large values of range and SD indicated greater variations among the four entries.

The other back vowel /o/ had an F0 mean of 341 Hz, a statistic range of 124 and an SD of 59. F1 had a mean of 489 Hz, a range of 159 and an SD of 66. F2 had a mean of 1365, a range of 209 and an SD of 101. F3 had a mean of 3233, a range of 284, and an SD of 135. F2 was the only one which was positively skewed as F0, F1, and F3 were all negatively skewed.

The last vowel /u/ had an F0 mean of 256 Hz, a range of 126 and an SD of 51. F1 had a mean of 399 Hz, a range 141 and an SD of 69. F2 had a mean of 1331 Hz, a range of 295 and an SD of 138. F3 had a mean of 2867 Hz, a range of 420 and an SD of 206. The small values for SD and statistical range indicated a small variation from the mean value.

Impressionistic description of EkeGusii sounds (Whiteley 1965, Cammenga 2002, Onkwani 2011) identified the vowels. This study has qualified the description with actual data for each of the seven vowels. The variations witnessed are best explained by the Source-Filter Theory as air passages or tubes are manipulated to produce various frequencies that compose the quality of a vowel sound.

4.1.2 EkeGusii vowel space

The most useful representation for the vowels, as used by phoneticians around the world, is a plot showing the average values for F1 and F2 for each vowel collected from a group of speakers

(Ladefoged & Disner 2012). This is because the most important descriptions for vowels, that is, height, backness and rounding features can be identified by the F1 and F2 frequencies of vowels, and, of course, to some extent F3. F1 describes the height feature while F2 identifies backness and rounding features. The heights have an inversed proportional relation with their F1 frequencies. The lower the F1 frequency, the higher the vowel is located.

For each of the subjects who were sampled for this research, a personal mean for each of the vowels was calculated. This was also summed with others within the group to have a group mean then the overall mean was calculated.

For the first male informant (RM1 henceforth), the vowel /i/ can be seen on the spectrograph for the /tVt/ and /tVβ/ contexts as below:

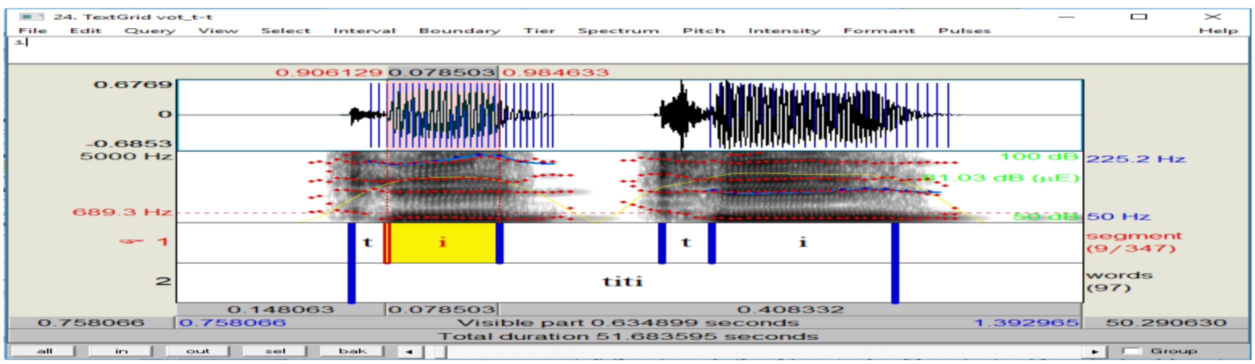


Figure 4.2 Vowel /i/ in the /tvt/ context.

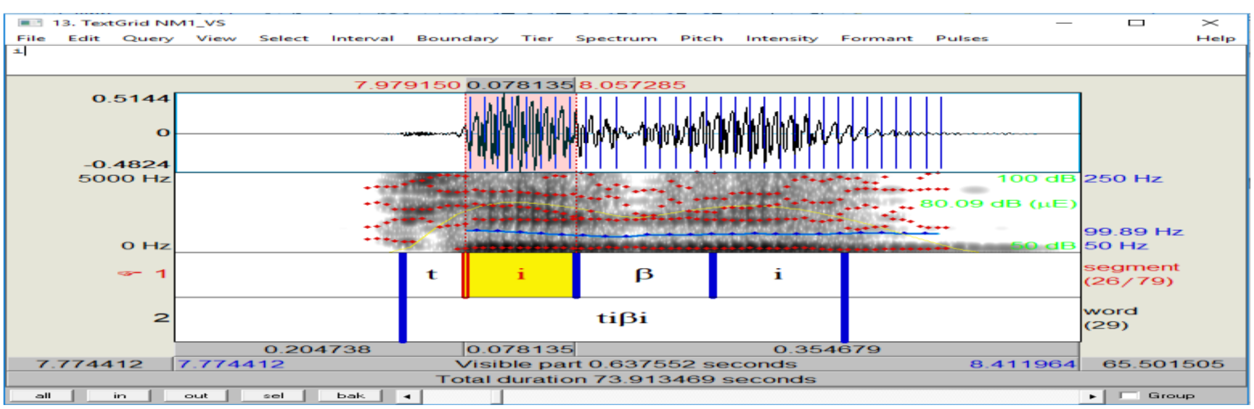


Figure 4.3: The vowel /i/ in the /tvβ/ context

These displays are spectrograms from the speech of RM1 vowel /i/ as deduced from words in the /tvt/ and /tvβ/ contexts with six repetitions. The dark bars in each of them are the formants of the vowel. F1 is the first dark bar and F2 is the second one from below showing the concentrations of energy as the air is filtered out from the source. The red lines are automatically generated through the middle of each dark bar. By clicking on these red lines at the point where the spectrograms look more stable, the formant frequencies of the vowel can be read in Hertz. Praat has a formant logger which enables the researcher to programme the details that can be listed from the TextGrid and sound files into the text file. The values were then exported to the Excel files for analysis. The following are the F2-F1 mean results for the male informant labeled RM1 for both the /tvt/ and /tvβ/ context.

Table 4.5 F2-F1 for informant RM1

Vowels	F2	F1
i	2096	256
e	1746	388
ɛ	1628	497
a	1270	610
ɔ	1170	541
o	1125	511
u	1212	305

The vowel chart for RM1 below, is based on the Tab. 4.5.

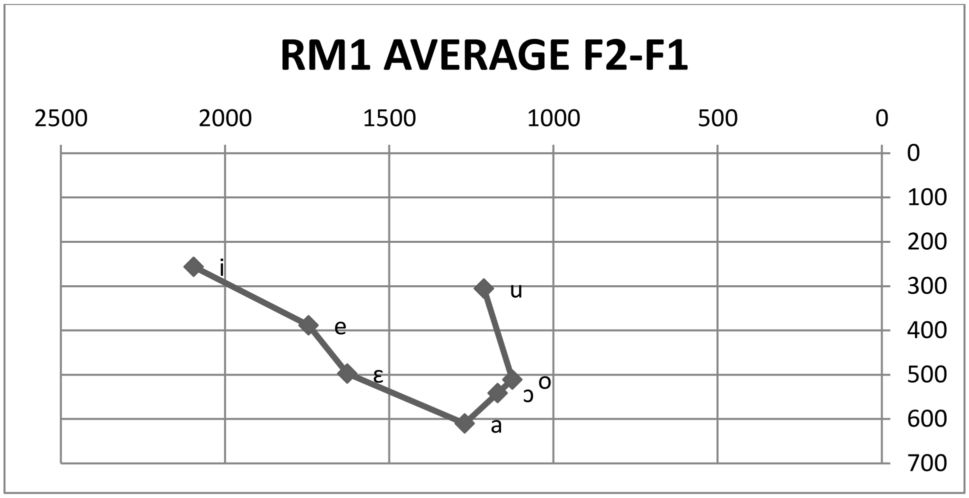


Figure 4.4 Vowel chart for RM1

The values show that this male, just like other males has lower frequencies as compared to the females and the children. This is attributed to male physiology (Ladefoged, 2002).

Table 4.6 shows the result in Hertz for all the vowels for the subject RM2 in the /tvt/ context. The result shows that /i/ and /u/ are the highest placed on the chart considering their F1 values. The lower the value the higher the vowel is in terms of tongue height.

Table 4.6 F2-F1 for informant RM2

RM2	**F2**	F1
i	2201	330
e	2021	395
ɛ	1867	471
a	1307	647
ɔ	1238	524
o	1010	422
u	1242	322

Tab.4.6 was used to come up with the personal vowel chart for RM2 which visually displays the differences F2-F1 create in positioning a vowel in its position.

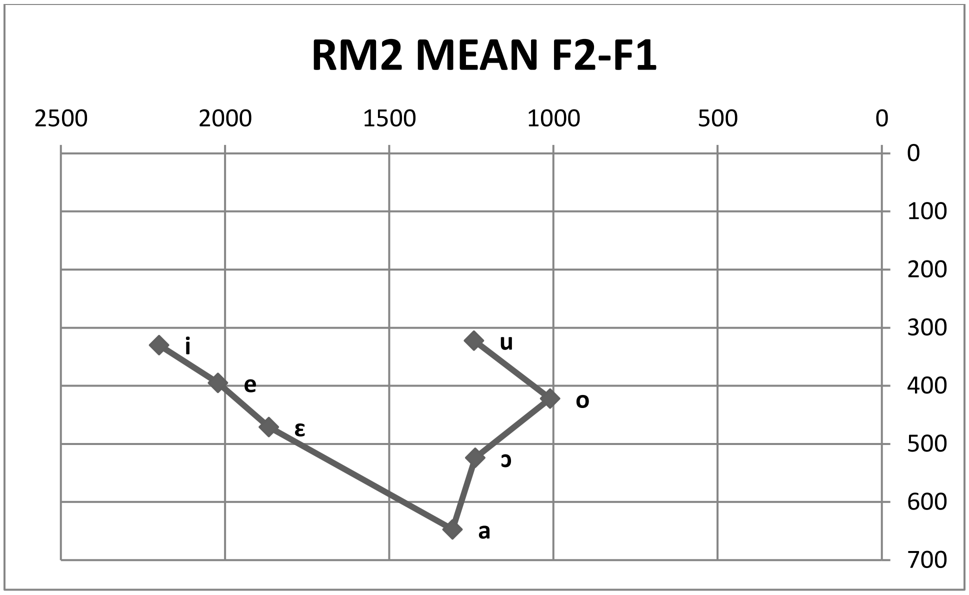


Figure 4.5 Vowel chart for RM2

The central vowel /a/ is drawn back to be within the 1000-1500 Hz block as are /u, o, ɔ/. It also indicated that the front vowels clustered together as did the back vowels for this informant.

Tab 4.7 gives the results for the third male informant MM3.

Table 4.7 F2-F1 for informant MM3

MM3	**F2**	F1
i	1965	382
e	2005	420
ɛ	1988	500
a	1535	718
ɔ	1243	565
o	1212	500
u	1140	381

The personal vowel chart for MM3 drawn from Tab 4.7 was as thus:

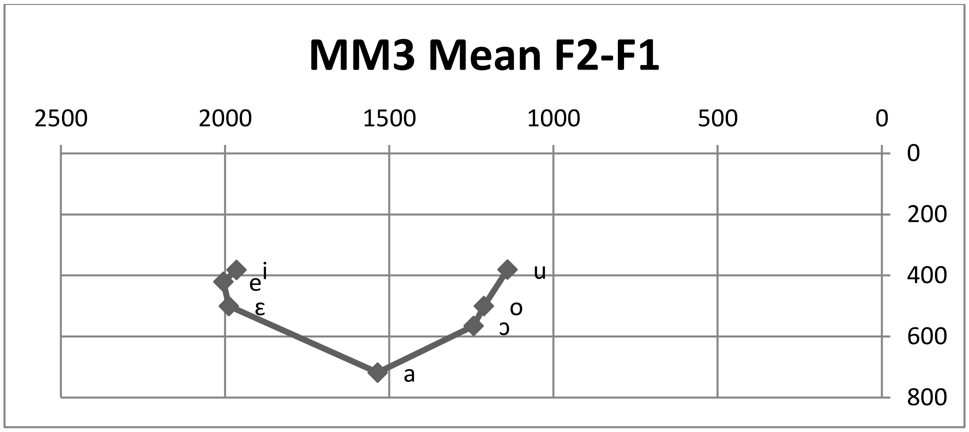


Figure 4.6 Vowel chart for MM3

The chart shows that the vowel sound /e/ was the most fronted with an F2 of 2005 Hz unlike all the informants with the vowel /i/ as the most fronted followed by /e/. The three front vowels /i, e, ɛ/ are very close together in terms of frontness with a range of only 40 Hz as the difference between /i/ at 1965 Hz and /e/ at 2005 Hz.

The central vowel /a/ was placed lowest as compared to the other male informants since it had an F1 was at 718 Hz. Its placement at the centre helped bring out the expected triangular shape for the vowels on the chart.

For the back vowels, this result indicated that /u/ was the backmost vowel with an F2 of 1140 Hz followed by /o/ with an F2 of 1212 Hz and then /ɔ/ with an F2 of 1243 Hz. /ɔ/ and /o/ were very close to each other with a range of 31 Hz between them.

In terms of height, /u/ was placed highest with an F1 of 381 Hz followed very closely by /i/ which recorded an F1 of 382 Hz. The front vowels were clustered together at the top but the back vowels were evenly spaced in their height positions.

Table 4.8 shows the mean for each of the vowels by the male informant labelled MM4 for /tVt/ context.

Table 4.8 F2-F1 for informant MM4

MM4	F2	F1
i	2329	267
e	2181	332
ɛ	1834	457
a	1660	584
ɔ	1362	470
o	1343	407
u	1387	312

Fig 4.6 is the graphical derivation of Tab 4.8 and it locates the grid points for each vowel as produced by the fourth male informant.

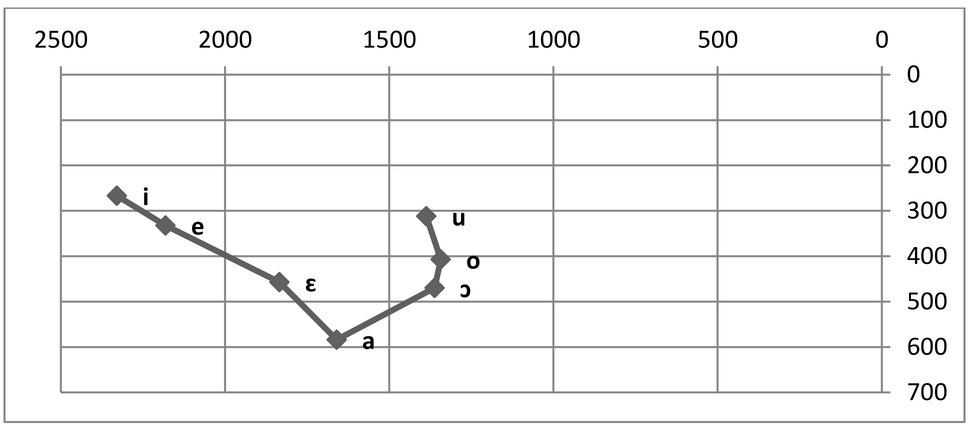


Figure 4.7 Vowel chart for MM4

The last male informant had /i/ as the highest placed vowel and most fronted with an F2 of 2329 Hz and an F1 267 Hz. /e/ follows with an F2 of 2181 Hz though /u/ is placed slightly higher than /e/ considering the F1 score of 332 Hz. However, different from the other male informants, the normal triangular shape for the vowels on the chart was perceived.

Ladefoged & Disner (2012) propose that a normal vowel chart for any language should typically have some kind of triangular shape which gives an even distribution of the front vowels, central vowels and back vowels. In this case, Ekegusii has three front vowels, one central vowel and three back vowels. This gives a semblance of the ideal vowel chart. The anomalies that might be visible from one context to the other and from speaker to speaker are regularized by subject and group means. Tab. 4.9 shows the means for each of the vowels by the males who were informants for this research.

Table 4.9 F2-F1 for adult male informants

Mean	F2	**F1**
i	2148	309
e	1988	384
ε	1829	481
a	1443	619
ɔ	1253	525
o	1173	460
u	1253	333

The resulting vowel chart for males is on Fig. 4.8.

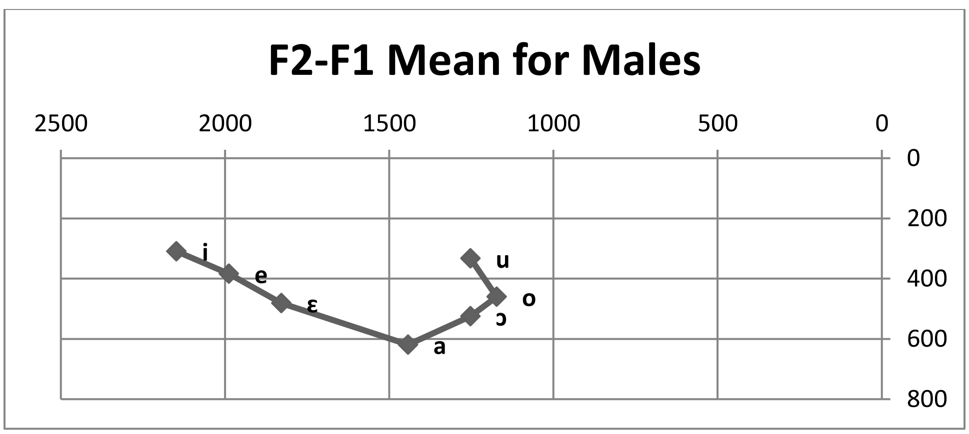


Figure 4.8 Vowel chart for males

For vowel /i/ the mean of 309 Hz for F1 and 2148 Hz for F2 should be lower than that of females and children. There is no big standard deviation for the men's frequencies which is F1 – 60 and F2 – 337. These values are within the norm of an F1 of 250-350 Hz according to Stevens (2000).

There is a slight variation though, when comparing the target vowels in the two contexts as seen above. The /tvt/ context records lower frequencies in overall than the /tvβ/ context. The reason can be explained from the nature of the final consonants, one being a voiceless stop and the other a voiced fricative which manipulate the outflowing air differently.

The vowel /e/ is the second most fronted vowel with an F2 of 1988 Hz. According to height, it is described as mid high in the literatures and we can see here that it records an F1 of 384 Hz which is within the range of mid high vowels.

At 1829 Hz for F2 and 481 Hz for F1, the vowel /ɛ/ comes next as mid low. It is obviously higher than /ɔ/ that it should correspond with in terms of height on the ideal vowel chart. The slight variation with /e/ is as a result of retracted tongue position.

These speakers have produced the central vowel /a/ which has the highest value for F1 at 619 Hz. It is therefore, the lowest vowel on this vowel chart. Notice that this vowel tends to lean more to the back than just central. It compares well in terms of F2 values by being close to all the F2 values of all the three back vowels being within a range of 200 Hz.

The mid low back vowel /ɔ/ records 1238 Hz for F2 and 528 Hz for F1. This is slightly lower in height as compared to the corresponding mid low front vowel. That also applies to vowel sound /o/ which records 1010 Hz for F2 and 422 Hz for F1. It is also slightly lower than the corresponding front mid high vowel. The vowel is also the furthest back as compared to all the three back vowels.

The vowel /u/ was the second highest by recording a low F1 value of 333 Hz. Unlike in the ideal vowel trapezium, this sound is not the backmost vowel as /o/ recorded a lower F2 of 1173 Hz as seen in Fig. 4.7 above.

The seven identified Ekegusii monophthongs produced by males are again normalized and plotted on triangular vowel space using the Lobanov (1971) procedure. The resulting vowel chart is on Fig. 4.8.

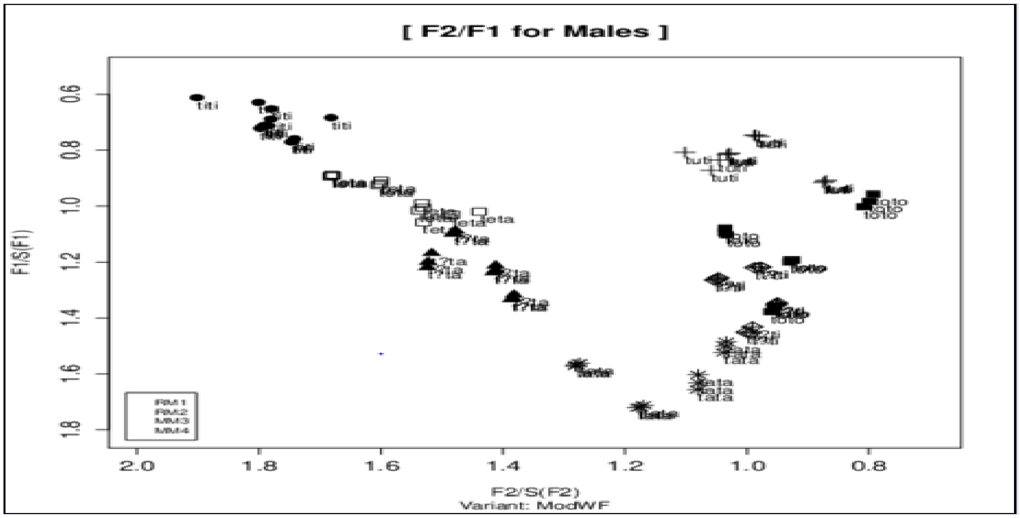


Figure 4. 9: F2/F1 plot for male speakers normalized after Lobanov (1971) algorithm.

Suffice it to say that the normal symmetry and arrangement of vowels was seen here in a triangular arrangement. Again, some little overlap is noticeable for the mid-high and mid-low for front and back vowels. This overlap could not be well explained by the source filter theory.

Table 4.10: F2-F1 for adult male informants' speakers of the Rogoro dialect

Rogoro Dialect F2 for males	RM1	RM2	Mean	Rogoro Dialect F1 for Males	RM1	RM2	Mean
i	**2096**	2201	**2149**	**i**	**330**	256	**293**
e	**1746**	2021	**1884**	**e**	**395**	388	**392**
ɛ	**1628**	1867	**1748**	**ɛ**	**471**	497	**484**
a	**1270**	1307	**1289**	**a**	**647**	610	**629**
ɔ	**1170**	1238	**1204**	**ɔ**	**524**	541	**533**
o	**1125**	1010	**1068**	**o**	**422**	511	**467**
u	**1212**	1242	**1227**	**u**	**322**	305	**314**

The averages for the F2-F1 for the male speakers of the Maate dialect of Ekegusii had a group chart as follows.

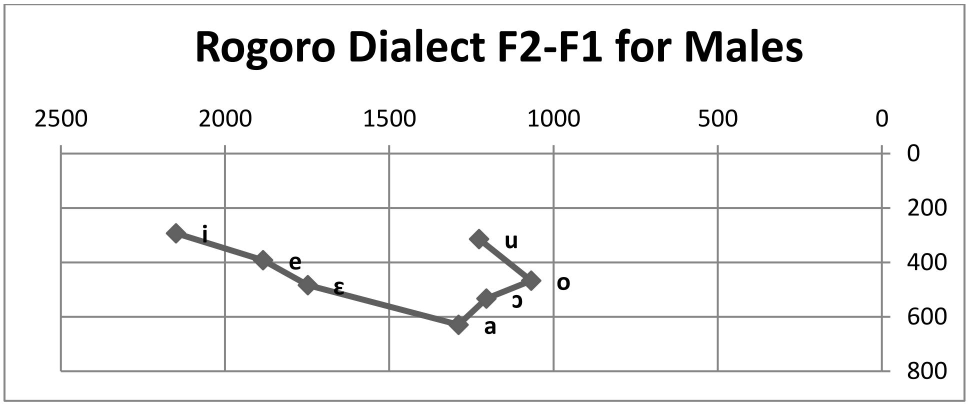


Figure 4.10 Vowel chart for adult male speakers of the Rogoro dialect

The vowel sound /i/ for these speakers was the most front and highest on the chart with an F2 of 2149 Hz and an F1 of 293 Hz. The mid high and mid low front vowels /e/ and /ɛ/ respectively are higher, considering their F1 values of 392 Hz and 484 Hz in the same order, than the mid high and mid low back vowels /o/ and /ɔ/. The central vowel /a/ was pulled more to the back than to the centre. The results of the male speakers of the Maate dialect of Ekegusii were as Tab. 411 shows.

Table 4.11 F2-F1 for adult male informants' speakers of the Maate dialect

Maate Dialect F2 for males	**MM3**	**MM4**	**Mean**	Maate Dialect F1 for Males	**MM3**	**MM4**	**Mean**
i	**1965**	2329	**2147**	**i**	**382**	267	**325**
e	**2005**	2181	**2093**	**e**	**420**	332	**376**
ɛ	**1988**	1834	**1911**	**ɛ**	**500**	457	**479**
a	**1535**	1660	**1598**	**a**	**718**	584	**651**
ɔ	**1243**	1362	**1303**	**ɔ**	**565**	470	**518**
o	**1212**	1343	**1278**	**o**	**500**	407	**454**
u	**1140**	1856	**1498**	**u**	**381**	325	**353**

The vowel chart got from the above averages for the males who speak the Maate dialect of Ekegusii is on Fig 4.9.

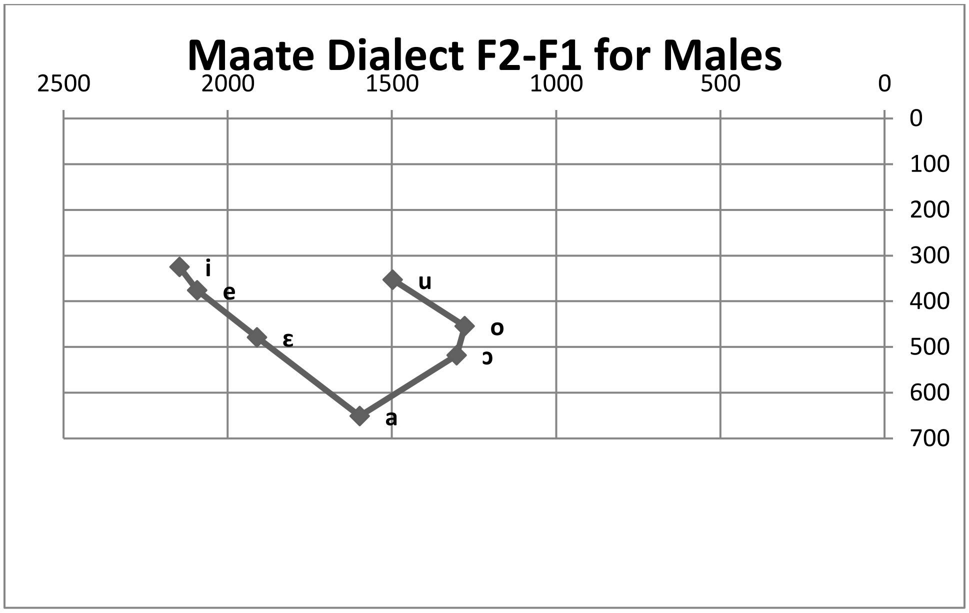


Figure 4.11 Vowel chart for adult male speakers of the Rogoro dialect

In general, the values for the second formant (F2) for the Maate dialect speakers were higher than those of the Rogoro dialect speakers. This was statistically significant as a Student's test carried on F2 parity yielded a p=0.002, a very high significance value unlike that of F1 which had a not significant p= 0.26. This means that the Maate males had their vowels moved to the front more than the Rogoro males hence the differences (Bosire, 1993). At the same time, the height measures (F1) had no significant differences between them as the significance test suggests chance deviations and not a pattern in the language. This can be appreciated more when we plot the two vowel charts on the same graph as seen on Fig 4.12.

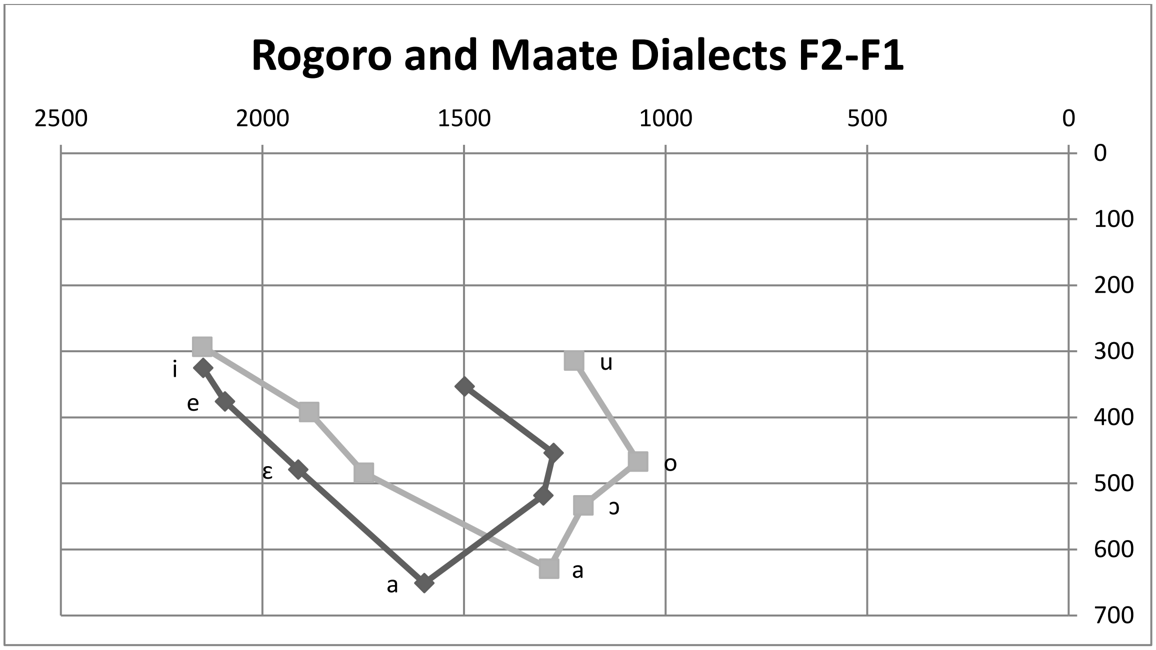


Figure 4.12 Vowel chart for adult male speakers of the Rogoro dialect (pale line) and Maate dialect (darker line)

The difference between the males of who speak Rogoro dialect, appearing in orange above, and those that speak Maate dialect (in blue) was seen only on the front-back distinction as the Maate speakers had their vowels pushed to the front more than those for the speakers of the Rogoro dialect. F1 difference between the two groups of speakers was $p>0.05$ which was not statistically significant but F2 had a significant difference of $p=0.002$.

The results for the female informants are on Tab. 4.12: the first female informant was labelled as MW1 with these values for F2-F1. We expect the values for the females to be higher than those of the males above owing to their anatomical difference; females have a shorter and less thick vocal tract.

Table 4.12 F2-F1 for informant MW1

MW1	F2	**F1**
i	2341	**368**
e	2213	**452**
ɛ	2072	**543**
a	1697	**647**
ɔ	1426	**495**
o	1322	**385**
u	1392	**356**

For this informant, the vowel /i/ maintained its characteristics with the biggest difference between F2 at 2341 Hz and F1 at 368 Hz. The highest vowel on the chart was /u/ with an average F1 of 356 Hz. Just like the other females as we shall see shortly, /u/ was not the backmost vowel on this table with 1392 Hz. /o/ recorded a mean F2 of 1322 Hz and F1 of 385 Hz. The mid low back vowel /ɔ/ had a mean F2 of 1426 Hz and F1 of 495 Hz. The central vowel /a/ is the lowest placed with the highest F1 value of 647 Hz and F2 of 1697 Hz. The mid low front vowel /ɛ/ had a mean F2 of 2072 Hz and F1 of 543 Hz. The other mid front vowel /e/ had an F2 of 2213 Hz and an F1 of 452 Hz.

Considering the table above, the personal vowel chart for MW1 was drawn as Fig 4.13.

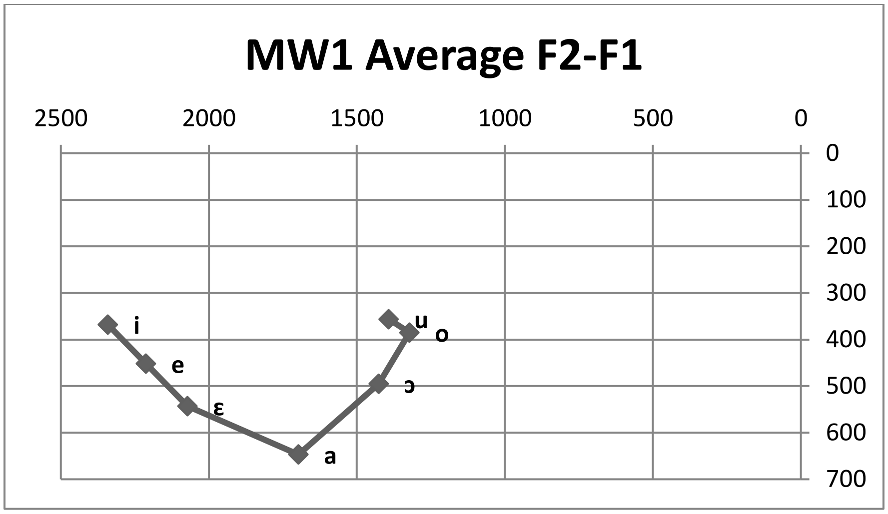


Figure 4.13 Vowel chart for MW1

The personal vowel chart for MW1 was almost like the group vowel chart for the females and the males save for minor personal differences. The uniqueness of the chart is the closeness between /u/ and /o/ in terms of backness (F2), and height (F1). Table 4.13 is for the second female informant labelled here as MW2.

Table 4.13 F2-F1 for informant MW2

MW2	F2	**F1**
i	2613	**351**
e	2289	**486**
ɛ	2141	**594**
a	1818	**777**
ɔ	1508	**564**
o	1346	**466**
u	1464	**415**

The table indicates higher formant values for MW2 as compared to MW1 above. The table was used to come up with the personal vowel chart for MW2 as seen below.

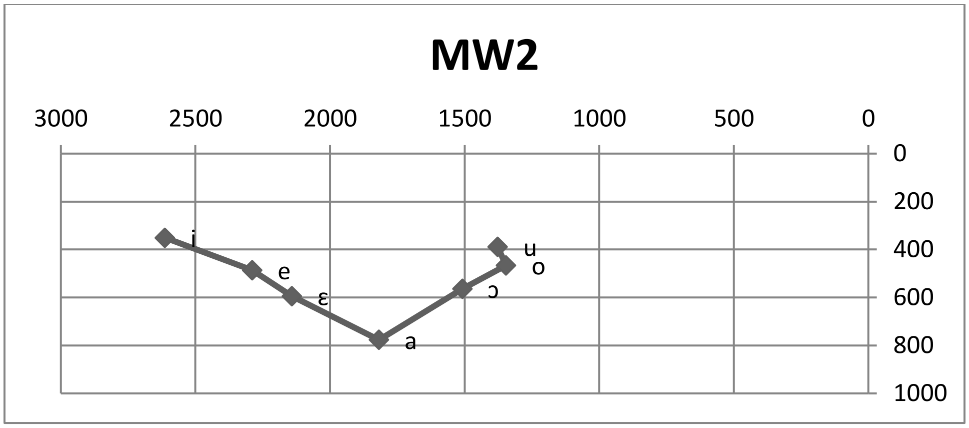


Figure 4.14 Vowel chart for MW2

MW2 has a small separation between the two mid front vowels /e/ and /ɛ/. The shape of the vowel chart still retains, though not identical, and the triangular formation as for the other speakers together with the mean vowel chart for the females was reflected by the vowels of this informant.

We now turn to the female informant labelled RW3 and see how her recorded voice is tracked in terms of F2 and F1 values for all the seven identified Ekegusii vowel sounds. The TextGrid helps in highlighting the target sound for analysis. Each target vowel for /tVt/ context was analysed separately before coming up with a unified mean.

Table 4.14 F2-F1mean values for RW3.

RW3	F2	**F1**
i	2146	**306**
e	1901	**437**
ɛ	1848	**536**
a	1780	**674**
ɔ	1500	**563**
o	1457	**451**
u	1520	**296**

The Tab. 4.14 was translated into a vowel chart Fig. 4.13.

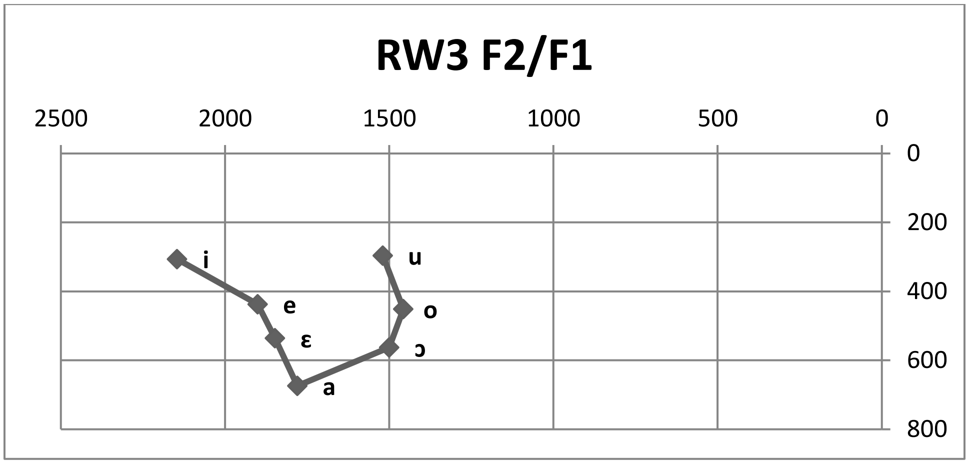


Figure 4.15 Vowel chart for RW3

Fig. 4.13 indicates very low values for F1 and F2 for all vowels as compared to those of other female informants already analysed above. The chart itself has the normal triangular shape as expected. These personal charts are not very consequential as the group scores are more representative.

Tab. 4.15 shows the results for F2-F1for the fourth female informant RW4.

Table 4.15 F2-F1mean values for RW4.

RW4	F2	**F1**
i	2137	**385**
e	1863	**429**
ɛ	1812	**507**
a	1684	**620**
ɔ	1431	**544**
o	1262	**499**
u	1296	**396**

Tab. 4.15 was used to construct the personal vowel chart for this female informant as follows.

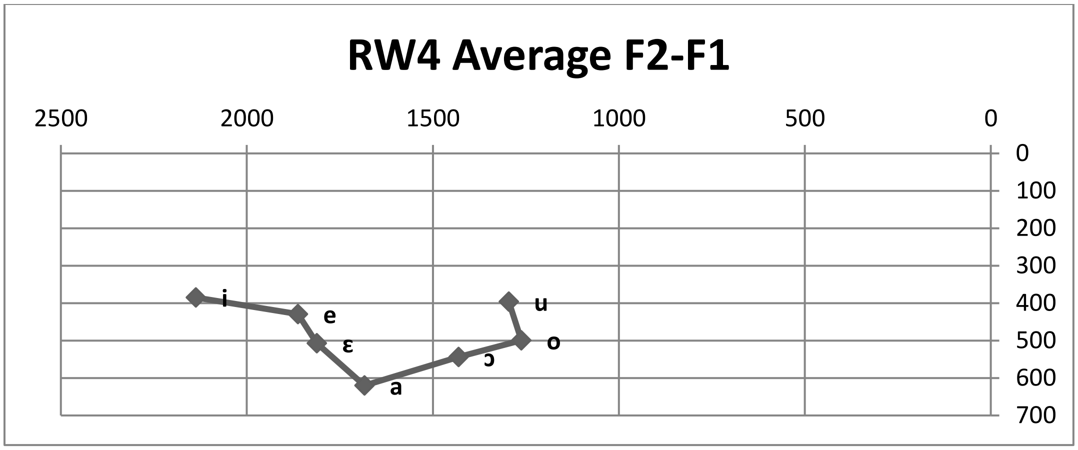


Figure 4.16 *Vowel chart for RW4*

For this informant, the vowel /i/ is the most fronted as expected with an F1 of 2137 Hz. The other front vowels, /e/ with an F2 of 1863 Hz and /ɛ/ with an F2 of 1812 Hz, are more to the centre than the front as they fall within the block range of 1500-2000 Hz with the actual range of 179 Hz. Another thing to note from this vowel chart is that the back vowel /o/ is the most back with an F2 of 1262 Hz (the lowest) as compared with the other two /ɔ/ (with an F2 of 1431 Hz) and /u/ (with an F2 of 1296 Hz).

Table 4.16 F2 values for adult females, mean and SD

F2	MW1	MW2	RW3	RW4	Mean	SD
i	**2341**	2613	**1850**	2137	**2235**	322
e	**2213**	2289	**1635**	1863	**2000**	306
ɛ	**2072**	2141	**1848**	1812	**1968**	163
a	**1697**	1818	**1780**	1684	**1745**	65
ɔ	**1426**	1508	**1500**	1431	**1466**	44
o	**1322**	1346	**1457**	1262	**1347**	82
u	**1392**	1377	**1520**	1296	**1396**	93

On the Tab.4.16, MW2 had the highest scores for F2 for all the vowels except for /e/. She is followed by MW1 for generally high values for the vowel sounds and lastly RW3 who recorded the lowest values for all the females and it is her plot that was most skewed from the expected mean.

F1 results for the females are summarized on Tab. 4.17.

Table 4.17 *F1 values for females, mean and SD*

F1	MW1	MW2	RW3	RW4	Mean	SD
i	368	351	452	385	389	44
e	452	486	560	429	482	57
ɛ	543	594	536	507	545	36
a	647	777	674	620	680	69
ɔ	495	564	563	544	542	32
o	385	466	530	499	470	62
u	356	389	296	396	359	46

Just like the Tab. 4.16 for F2 above, F1 also displays the same results with MW2 recording the highest values generally. RW3 also records high values for F1. The lowest F1 values were recorded by MW1.

The Tab. 4.18 shows the mean F2-F1 average values for all the female informants for this study.

Table 4.17 F2-F1 average for females

Adult Females	F2	F1
i	2235	389
e	2000	482
ɛ	1968	545
a	1745	680
ɔ	1466	542
o	1347	470
u	1396	359

Tab. 4.19 was used to draw Fig. 4.17, a vowel chart for females.

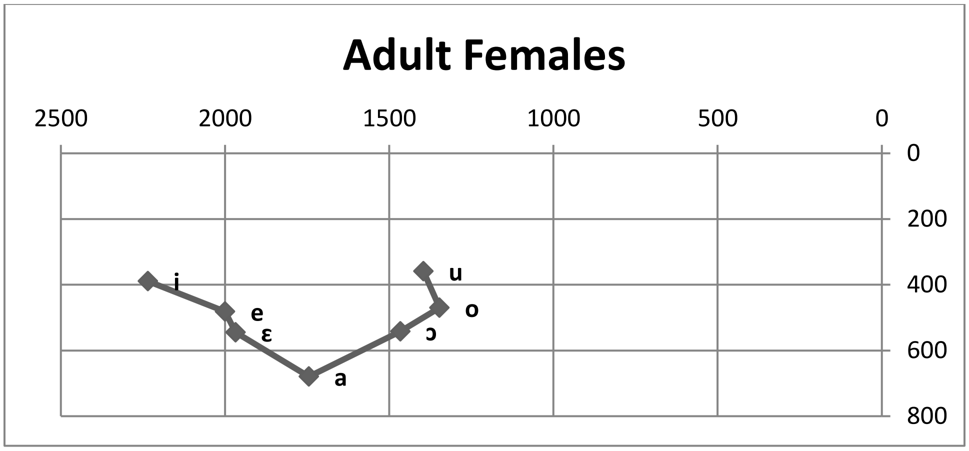


Figure 4.17 Vowel chart for females

The highest and most fronted vowel sound in Ekegusii for the female informants was /i/ with F2 at 2235 Hz and F1 at 408 Hz. The other front vowels are /e/ with an F2 of 1968 Hz and F1 at 482 Hz and /ɛ/ with F2 of 1968 Hz and F1 of 522 Hz.

The only central vowel in Ekegusii /a/ recorded an average F2 of 1745 Hz and 680 Hz for F1. In comparison with the results for males at 1443 Hz and 619 Hz for F2 and F1 respectively, the females have a much lower /a/ and it was pushed a bit to the front based on the F2 values which was 274 Hz more than for the males' F2 value.

For the back vowels, the vowel /u/ is the highest with an F1 of 366 Hz but it is not the backmost considering its F2 of 1418 Hz. The next vowel is /o/ which is the backmost vowel for the females with an F2 of 1384 Hz and the attending F1 of 470 Hz. The last back vowel is /ɔ/ which recorded an F2 of 1540 Hz and an F1 of 542 Hz.

The values for female informants were normalized after Lobanov (1971) procedure. The resulting vowel chart is Fig. 4.18.

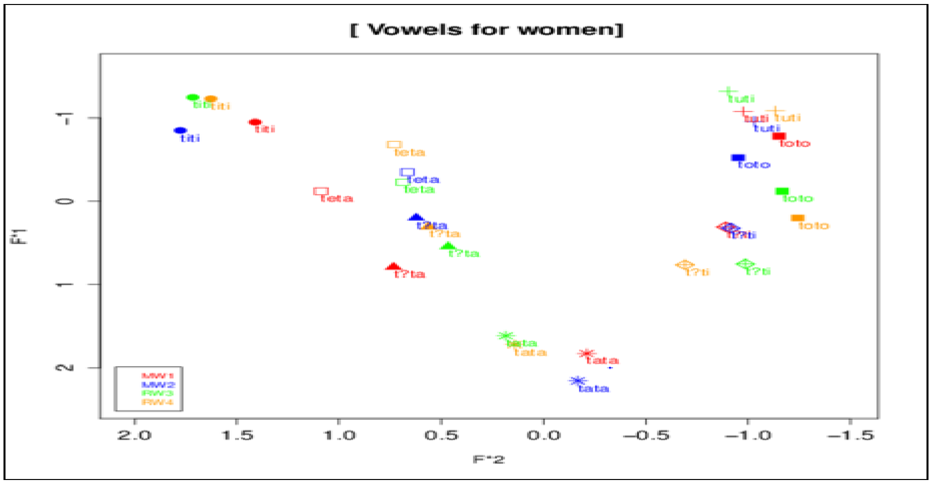


Figure 4.18: F2/F1 plot for adult female speakers normalized after Lobanov (1971) algorithm.

Fig. 4.18 draws the seven Ekegusii vowels on their acoustic spaces as produced by the female subjects. The values for each vowel are very close for all the four females indicating greater homogeneity in the dispersion of the vowels.

The four females in this study were selected from the two Ekegusii dialects. MW1 and MW2 are speakers of the Maate dialect while RW3 and RW4 are speakers of the Rogoro dialect. Slight variations were noticed in the vowels especially for the second formant (F2) whereby the Maate female speakers of Ekegusii recorded higher values meaning that their vowels were more fronted than those of the females who speak the Rogoro dialect of Ekegusii which was consistent with the results of males whereby those who speak the Maate dialect had the vowels with higher F2 values than those who speak the Rogoro dialect. The following are results for females from the two dialects of Ekegusii beginning with speakers of Maate dialect.

Table 4.18 F2-F1 average for female speakers of Maate dialect

vowels	F2	F2 SD	F1	F1 SD
i	2477	192	398	42
e	2186	38	469	24
ε	2107	49	523	29
a	1758	86	712	92
ɔ	1614	265	530	49
o	1409	123	426	57
u	1428	51	386	42

The SD ranged from 24 to 92. The vowels with low SDs like /e/ and /ε/ showed that all the tokens from the informants were close together. Tab. 4.19 was used to come up with the vowel chart for the female Ekegusii speakers of Maate dialect.

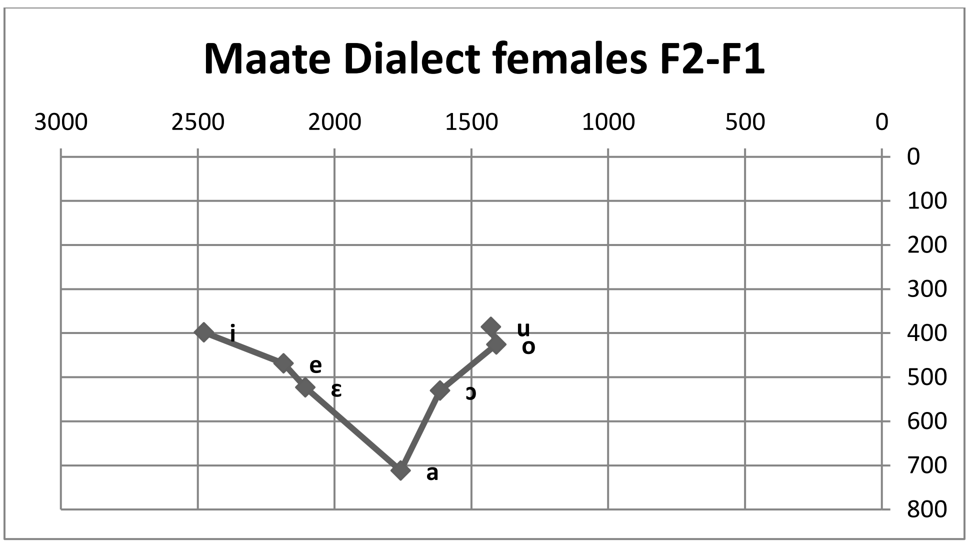


Figure 4.19 Vowel chart for female speakers of Maate dialect

The vowel sound /i/ was seen to be the most front vowel with an F2 of 2477 Hz. /e/ followed with an F2 of 2186 Hz and /ε/ 2107 Hz. The backmost vowel for these speakers was /o/ with an F2 of 1409 Hz then followed by /u/ with an F2 of 1428 Hz. /ɔ/ was more drawn to the centre with an F2 of 1614 Hz.

In terms of height, the central vowel /a/ was below the F1 700 Hz mark at 712Hz. /u/ was the highest vowel on the chart with an F1 of 386 Hz followed by /i/ with an F1 of 398 Hz. /o/ was next in height with an F1 of 426 Hz, /e/ had 469 Hz, /ɛ/ had 523 Hz, /ɔ/ had 530 Hz and lastly /a/ with 712 Hz.

Let us now compare the above results with the female speakers of the Rogoro dialect of Ekegusii as seen on Tab. 4.20.

Table 4.19 F2-F1 Average for female Speakers of Rogoro Dialect

Vowels F2	RW3	**RW4**	Mean	**SD**	**Vowels F1**	RW3	**RW4**	Mean	**SD**
i	1850	**2137**	1994	**203**	**i**	452	**385**	419	**47**
e	1635	**1863**	1749	**161**	**e**	560	**429**	495	**93**
ɛ	1848	**1812**	1830	**25**	**ɛ**	536	**507**	522	**21**
a	1780	**1684**	1732	**68**	**a**	674	**620**	647	**38**
ɔ	1500	**1431**	1466	**49**	**ɔ**	563	**544**	554	**13**
o	1457	**1262**	1360	**138**	**o**	530	**499**	515	**22**
u	1520	**1296**	1408	**158**	**u**	296	**396**	346	**71**

Tab. 4.20 was used to come up with the vowel chart for the female speakers of the Rogoro dialect of Ekegusii Fig. 4.16.

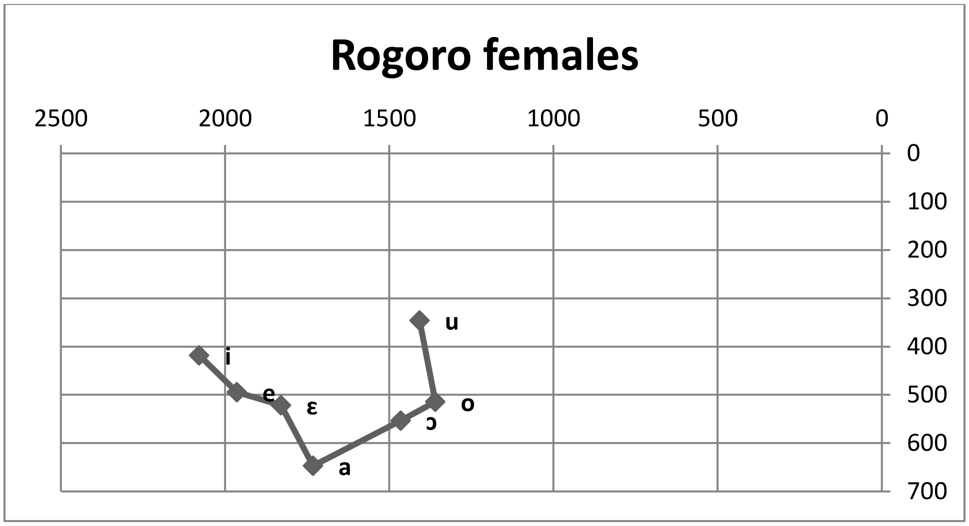


Figure 4.20 *Vowel chart for female speakers of Rogoro dialect*

The female speakers of the Rogoro dialect had far much lower scores for the second formant making the front vowels to seem drawn to the center. The vowels /i, e, ɛ, a/ all fall within the 1500-2000 Hz bracket. In comparison with the female speakers of the Maate dialect, these vowels are a bit drawn to the back.

In terms of height, the highest vowel was /u/ with an F1 of 346 Hz followed by /i/ with 419 Hz then /e/ at 495 Hz, /ɔ/ at 515 Hz, /ɛ/ at 522 Hz and lastly the lowest was /a/ with 647 Hz. The vowels for the females who speak the Rogoro dialect were clustered much close together unlike the Maate dialect speakers who had their vowels a bit more widely dispersed on the vowel chart. The differences can be appreciated more when the two vowel charts, for the Rogoro and Maate dialect, are plotted on the same graph as below.

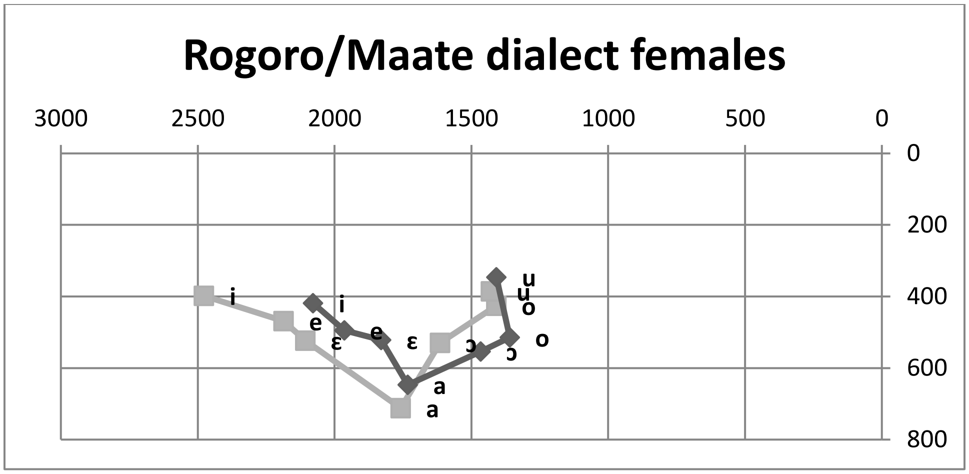


Figure 4.21 Vowel chart for female speakers of Rogoro and Maate dialects side by side

The females who speak the Maate dialect, the ones in pale hue on Fig. 4.21, have the vowels moved to the front as compared to those female speakers of the Rogoro dialect, here represented in a darker plot. There was no big variation in terms of height (F1) for the females just like there was no significant difference between the male speakers of the Maate and Rogoro dialects. The difference was in the F2 values that showed a difference of p=0.005 which was highly significant.

The following are the results for children beginning with the first male child labeled RCM1.

Table 4.20 F2-F1 averages for child informant RCM1

RCM1 Vowels	F2	**F1**
i	1795	**411**
e	1714	**445**
ɛ	1654	**510**
a	1359	**656**
ɔ	1239	**567**
o	1194	**479**
u	1342	**329**

Tab. 4.22 was used to draw a personal vowel chart for this child informant.

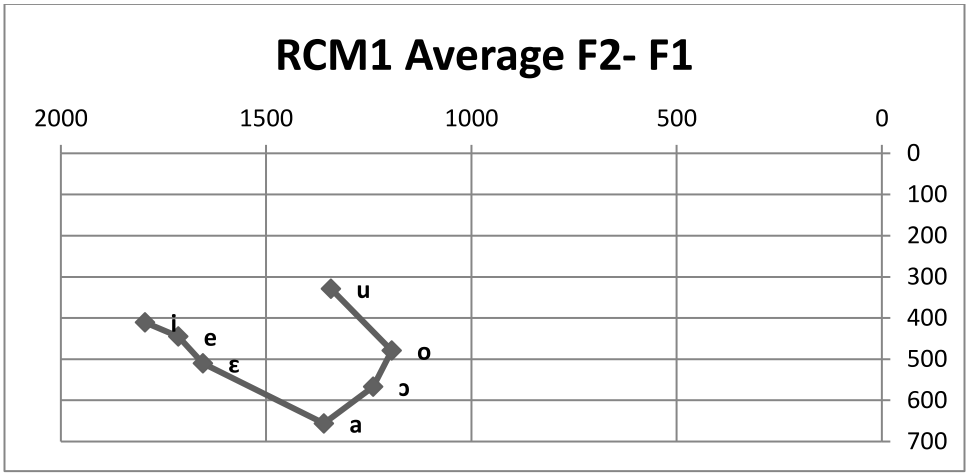


Figure 4.22 Vowel chart for first male child informant RCM1

This informant had the front vowels /i,e,ɛ/ very close together in height (considering F1 values) with only a range of 99 Hz. They were also very close in terms of their frontness since the minimum F2 score was 1654 Hz and the maximum F2 was 1795 Hz. This means that the front vowels are lumped up together very close to the center.

The central vowel /a/ was skewed to the back with an F2 of 1359 almost like the back vowels. The central vowel falls within the same block of front-back variation within a 1000-1500 Hz block.

For the back vowels, /o/ was the backmost with an F2 of 1194 Hz. This was followed by /ɔ/ and then /u/. Unlike the ideal vowel chart, the highest back vowel /u/ is not also the backmost.

The next child informant was labeled MCM1 and Tab. 4.22 gives the results.

Table 4.21 F2-F1 averages for child informant MCM1

MCM1 Vowels	F2	**F1**
i	2302	**367**
e	2011	**495**
ɛ	1979	**648**
a	1843	**925**
ɔ	1304	**678**
o	1282	**503**
u	1173	**445**

The personal chart derived from Tab. 4.23 is seen on Fig. 4.21.

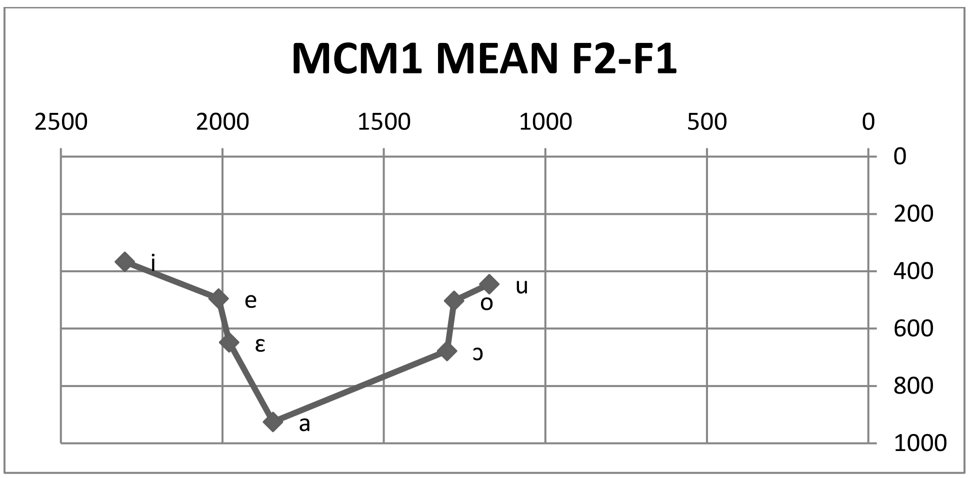


Figure 4.23 Vowel chart for first male child informant MCM1

This informant had higher values for nearly all the vowels for both F2 and F1 as compared to RCM1. /i/ recorded an F2 of 2302 Hz and an F1 of 367 Hz. The high F2 and lowest F1 means are translated to mean that /i/ is the most fronted and highest vowel on the chart. /e/ and /ɛ/ were close in terms of frontness and height.

The central vowel /a/ was pushed to the front more than the first child informant. It is also the lowest placed vowel with the highest F1 of 925 Hz.

The back vowel /u/ was placed highest on the table with an F2 of 1173 Hz and an F1 of 445 Hz. /u/ is also the backmost vowel on the chart. The back vowels are very close to each other yet the entire chart has the expected triangular shape in all.

Tab. 4.22 gives the results for the third child informant labeled RCF1.

Table 4.22 F2-F1 for first female child informant RCF1

RCF1 Vowels	F2	**F1**
i	2695	**313**
e	2612	**442**
ɛ	2512	**561**
a	1501	**707**
ɔ	1318	**611**
o	1491	**408**
u	1468	**353**

Tab. 4.24 was used to come up with the following vowel chart for the first child female informant RCF1.

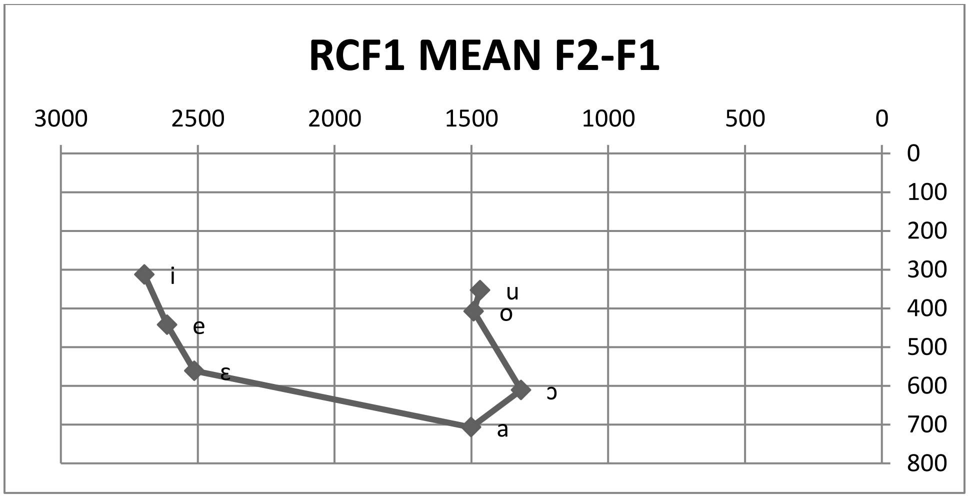


Figure 4.24 Vowel chart for first female child informant RCF1

This female child informant had higher means for both F1 and F2 on average. The central vowel /a/ had an F2 of 1501 Hz. This vowel was drawn also to the back with an F2 range of 182. The expected triangular shape of the chart is still discernable.

The last child informant was labeled MCF2 and she presented the results in Tab. 4.25.

Table 4.23 F2-F1 for second female child informant MCF2

MCF2 Vowels	F2	F1
i	2766	**378**
e	2604	**456**
ɛ	2479	**658**
a	1737	**888**
ɔ	1318	**654**
o	1283	**567**
u	1260	**470**

The values on the Tab. 4.25 were used to come up with Fig. 4.25 that plotted the vowels of this informant on her personal vowel chart.

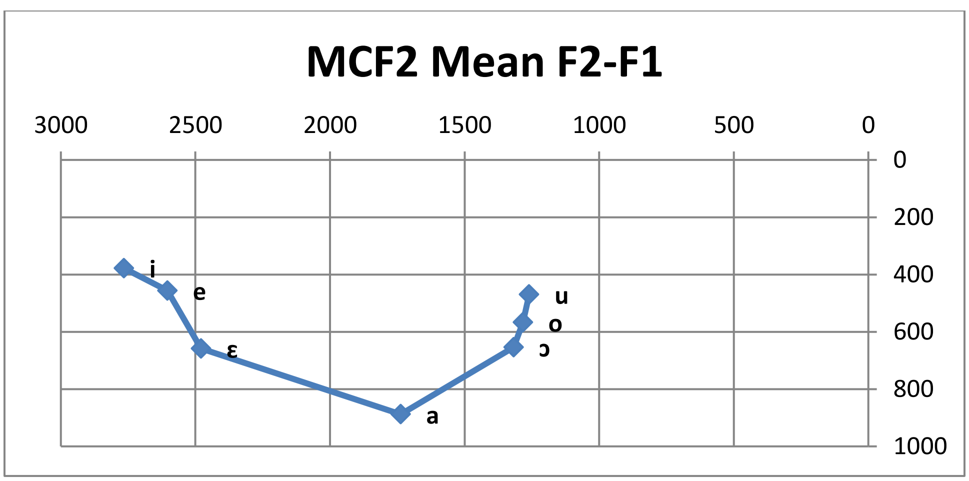


Figure 4.25 Vowel chart for second female child informant MCF2

The front high vowel /i/ recorded an F2 of 2766 Hz and an F1 of 378 Hz. /e/ was also very high and fronted recording 2604 Hz for F2 and 456 Hz for F1. The mid low vowel /ɛ/ recorded2479 Hz for F2 and 658 for F1which is expected of children. The central vowel /a/ was seen to have a high F2 score of 1737 Hz and a very high F1 of 888Hz.

The back vowels were very close together for both F1 and F2. The highest back vowel /u/ had 1260 Hz for F2 and 470 Hz for F1. /o/ had 1283 Hz for F2 and 567 Hz for F1. The vowel /ɔ/ had a mean F2 of 1318 Hz and 654 Hz for F1. There was no significant difference between this speaker and the others except for the central vowel which was more fronted than RCF1. This could be a dialectal difference.

The average duration for children was captured aptly on Tab 4.24.

Table 4.24 F2-F1 average for children informants

Vowels	F2	**F1**
i	2390	**392**
e	2235	**460**
ɛ	2156	**594**
a	1535	**794**
ɔ	1295	**628**
o	1365	**489**
u	1331	**399**

The results on this table are better appreciated when displayed on the following scatter plot that shows collective vowel chart for children.

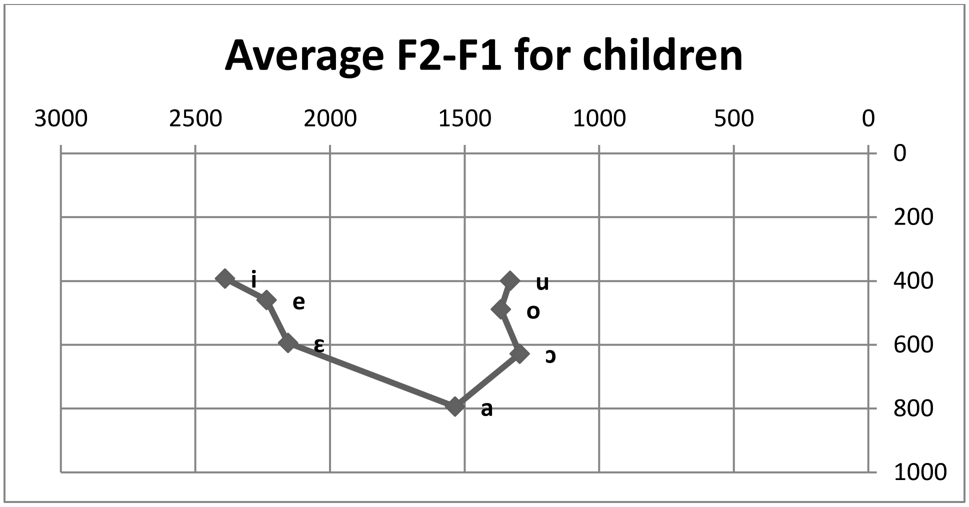


Figure 4.26 F2-F1 plot for children informants

For the children, the vowel /i/ is the highest and most fronted vowel. The vowel /i/ for the children recorded an average F2 of 2390 Hz and F1 of 392 Hz. This was higher and more fronted than the values recorded for the males and females respectively. The vowel sound /e/ also recorded 2235 Hz for F2 and 460 Hz for F1. This was also within the block of 2000-2500 Hz indicating the frontness of the vowel. To complete the front vowels, /ɛ/ recorded 2156 Hz for F2 and 594 Hz for F1. The vowel was slightly drawn to the centre and lower than the other mid-front vowel /e/ as expected.

The central vowel /a/ was drawn more to the back than being at the centre. This was evidenced by the F2 value of 1535 Hz and F1 value of 794 Hz. At almost 800Hz for F1, this vowel was placed very low on the vowel chart for the children as compared to the average results for adult males and females respectively.

The highest placed back vowel was /u/ with a mean of 1331 Hz for F2 and 399 HZ for F1. With an F2 of 1331 Hz, the vowel is a back vowel except when we compare this with the results of males and females whose back vowels recorded very low values placing them farther back on the chart. The vowel sound /e/ recorded 1365 Hz for F2 and 489 Hz for F1. The vowel /ɛ/ was the back most of the three back vowels. It had an F2 of 1295 Hz and an F1 of 628 Hz. This was unlike the males and females who had /e/ as the one with the smallest value of F2, pushing it to the back more than the other two back vowels.

The vowel data for F2/F1were also normalized using Lobanov procedure. This yielded the following vowel chart which differentiates each vowel and speaker. The vowels occupied respective space on the chart an indication of greater homogeneity for children informants. Fig. 4.24 shows the normalized vowels for children.

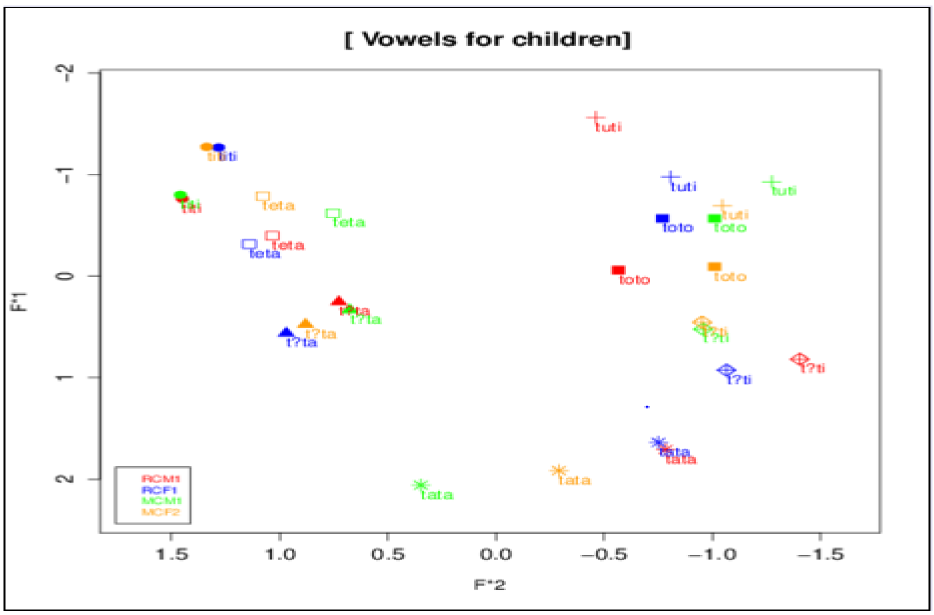


Table 4.27 F2-F1 Lobanov normalized vowels for children informants

There was evidence from the data that the vowel chart for the children who speak the Rogoro dialect was different from that of the children who speak the Maate dialect. Tab. 4.27 gives the mean results for Rogoro children.

Table 4.25 F2-F1 average for children informants, speakers of the Rogoro dialect

Vowels	F2	**F1**
i	2245	**362**
e	2163	**444**
ε	2083	**536**
a	1430	**682**
ɔ	1279	**589**
o	1447	**444**
u	1446	**341**

Tab. 4.27 was used to come up with the vowel chart for the children who speak the Rogoro dialect.

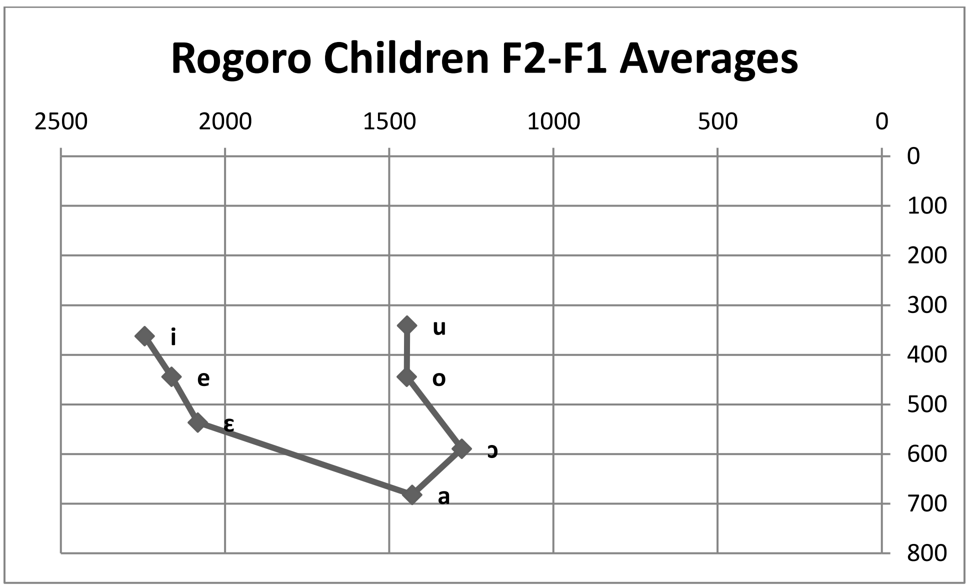


Figure 4.28 F2-F1 plots for children informants, speakers of the Rogoro dialect

For the Rogoro children, the vowel sound /i/ had an F2 of 2245 Hz and 362 Hz for F1. /e/ had an F2 of 2163 Hz and F1 had a mean of 444 Hz. /ε/ had a mean of 2083 Hz for F2 and 536 Hz for F1.

The central vowel for the Rogoro children was actually at the back on the same line with the back vowels. It recorded an F2 of 1430 Hz and an F1 of 682 Hz. This was contrasted to the more fronted much lower /a/ for the Maate speakers as we shall see below.

The back vowel /u/ had 1446 Hz for F2 and 341 Hz for F1. This was slightly higher in terms of height in comparison to the front high vowel /i/. The vowel /o/ recorded 1447 Hz for F2 and 444 Hz for F1. Incidentally, this is the same value for the front mid-high vowel /e/. the vowel sound /ɛ/ had a mean of 1430 Hz for F2 and 682 Hz for F1.

Tab. 4.28 details the F2-F1 scores for the children who speak the Maate dialect of EkeGusii.

Table 4.26 F2-F1 average for children informants who speak Maate dialect

Vowels	F2	**F1**
i	2534	**422**
e	2308	**476**
ɛ	2229	**653**
a	1790	**907**
ɔ	1311	**666**
o	1283	**535**
u	1217	**458**

Tab 4.28 was used to draw the following vowel chart for the speakers of Maate dialect.

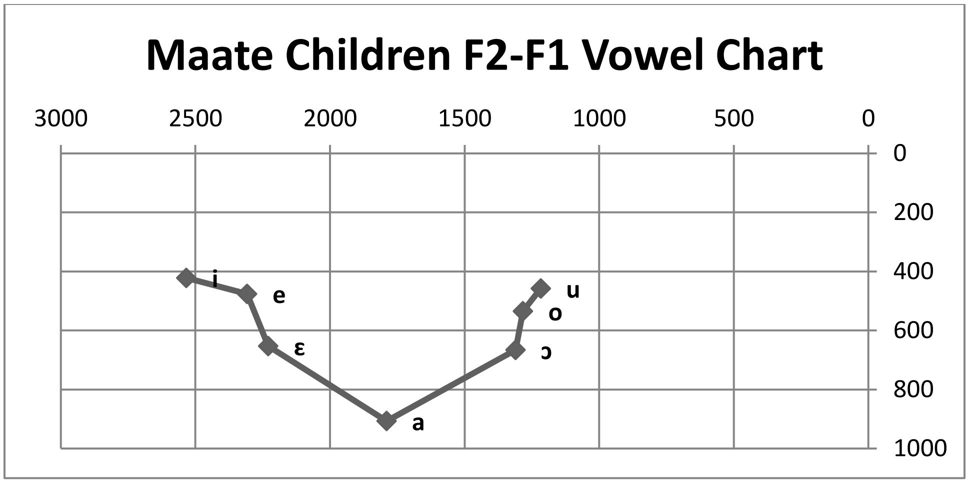


Figure 4.29 F2-F1 plots for children informants, speakers of the Maate dialect

For the Maate children, vowel sound /i/ was the frontmost and highest located on the chart with an F2 of 2534 Hz and an F1 of 422 Hz. /e/ recorded a mean of 2308 Hz for F2 and 476 Hz for F1. /ɛ/ had 2229 Hz for F2 and 653 Hz for F1. All the front vowels were way too fronted when compared to the values of the children who speak the Rogoro dialect.

The central vowel /a/ is seen to sit at the centre between the front and back vowels. /a/ recorded 1790 Hz for F2 and 907 for F1. The vowel /a/ was more fronted and far much lower placed than that for the speakers of the Rogoro dialect. This is a pattern seen for the adult males and females in this research.

The back vowel /u/ had 1217 Hz for F2 and 458 Hz for F1. /o/ was at 1283 Hz for F2 and 535 Hz for F1. The vowel sound /ɔ/ had 1311 Hz for for F2 and 666 Hz for F1. The difference among the back vowels for the children of Maate and Rogoro was not significant. This can be appreciated when we plot the two vowel charts on the same graph.

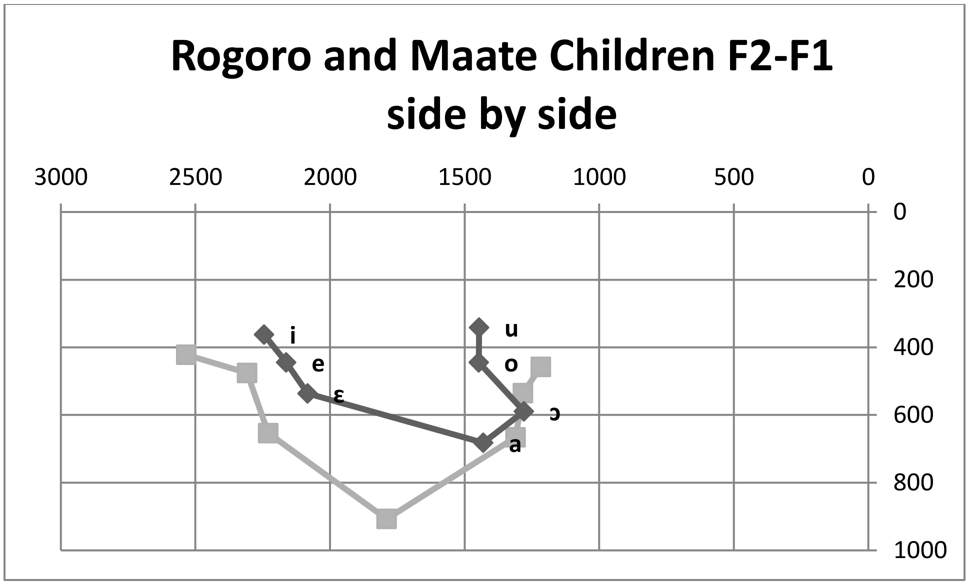


Figure 4.30 Rogoro and Maate Children F2-F1 side by side Rogoro dialect in darker hue and Maate dialect in pale hue

The Maate dialect had its vowels more spread out to the front and back as evidenced on Fig. 4.30. The Maate vowels are generally lower and more to the front for the front vowels and more to the back for the back vowels. The Rogoro vowels are a bit clustered to the centre. The differences between the values for each vowel were statistically significant with the p-value ranging from 0.002 – 0.004.

The reference point for all languages concerning the vowel chart is the vowel trapezium as devised initially by Daniel Jones (1917). The cardinal vowel positions are fixed points which describe the given standard quality of vowelness at this relative position. The actual realization of a vowel in Ekegusii, for this matter, will obviously show some variation from that ideal point because of the inherent phonotactics at play in Ekegusii. The notions high versus low and front versus back are not strictly tongue positions but indicators of the way a vowel sounds here relative to another in auditory terms (Ladefoged & Johnson 2011:89).

The normalized vowel chart with all the speakers in one plot is presented in Fig. 4.31 below.

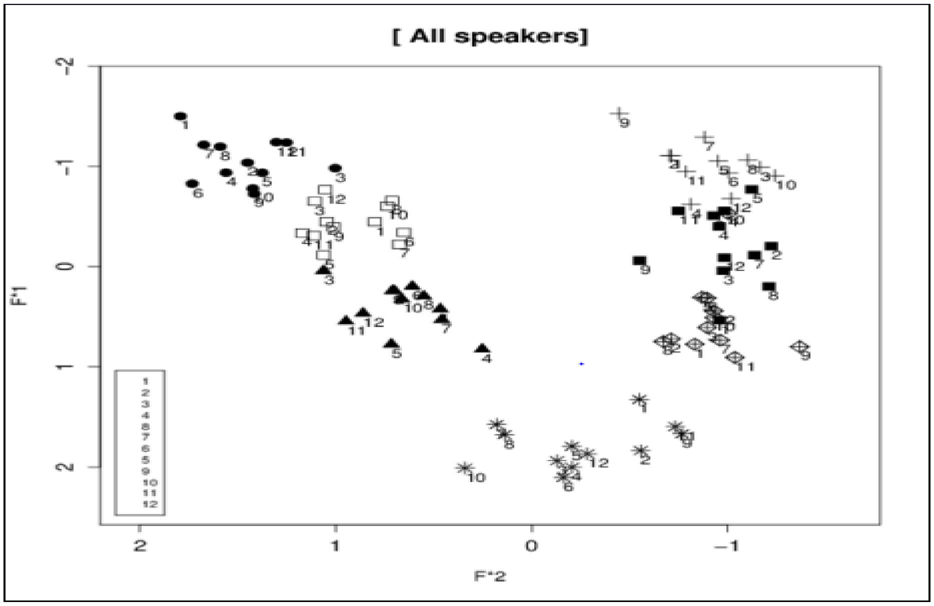


Figure 4.31: Normalized vowel chart with all the 12 speakers in one plot

The normalized values indicate the same trajectory for all the seven vowels identified with numbers 1-7 as /i e ɛ a ɔ o u/ respectively. All vowels are separated in terms of height and backness as expected. However, there is some overlap within vowel spaces at the back with /u o ɔ/ being very close. The central, low vowel /a/ has a greater dispersion too with some speakers having theirs pushed to the front and others a bit to the back though within the same range.

The source Filter theory adopted by this research gives a guide in understanding of the vowels of Ekegusii. The production of different vowels is possible by altering the size and shape of vocal tract organs, mostly throat and mouth. As the air is put in motion through the vibration of vocal folds, as they open and close, air above the vocal folds will also vibrate. These vibrations will be in more than one way. The various vibrations or resonances are what we measure as formants which give cue to much of what happens during the production of a vowel in acoustic terms.

4.1.1.1 Front vowels

The front vowels in Ekegusii are [i, e, ɛ]. On this chart, /i/ the highest and most fronted of the seven identified Ekegusii vowels for males and for females as well. It records the highest figures for F2 at 2199 Hz and also the lowest F1 at 352 Hz. The values for /i/ are close to the range of 250-350 Hz as indicated by Stevens (2000) in order to be classified as a high vowel.

The analysis of the spectrogram reveals the characteristic thin and not so broad low-frequency dip after the first spectral peak. The same shape is replicated for both the spectral shape of MM4 and MW2 as seen on Fig. 4.32

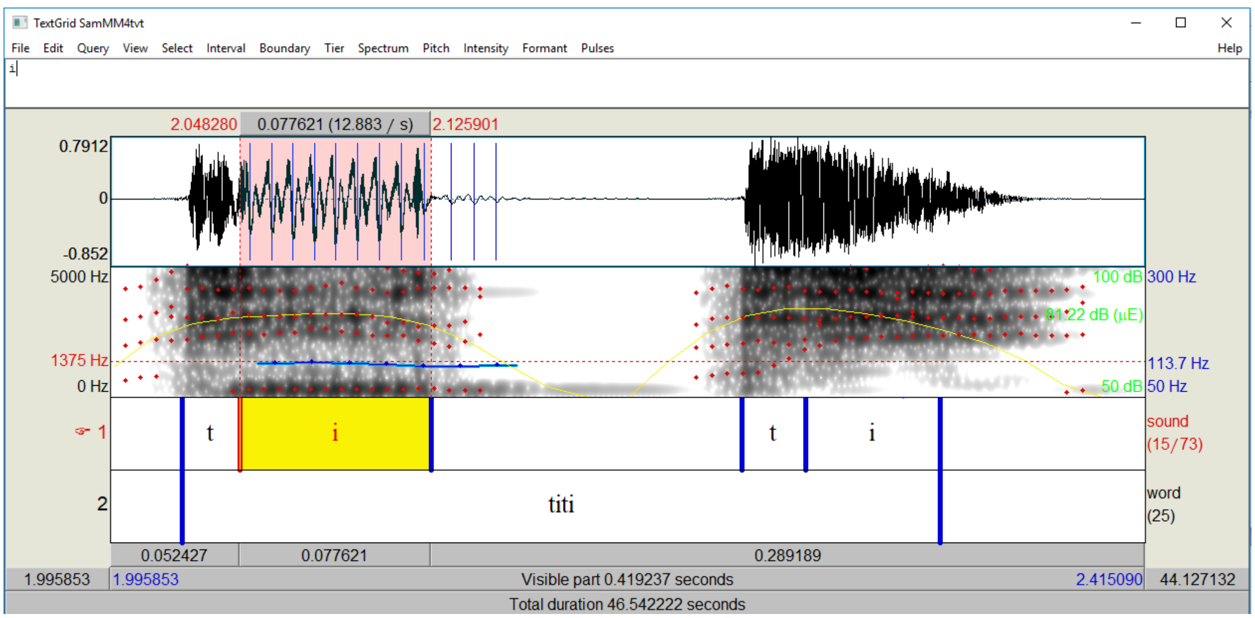


Figure 4.32 MM4 spectrogram and waveform for /titi/

The above spectrogram and waveform for MM4 compares well with that of RW4 in terms of size and shape as noted earlier.

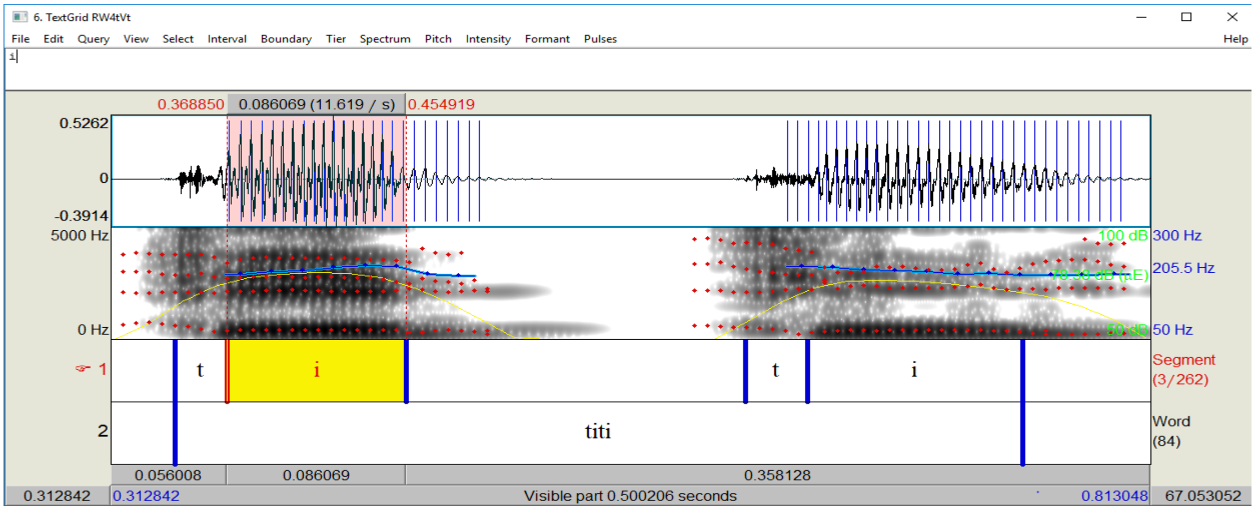


Figure 4.33 RW4 spectrogram and waveform for /titi/

Sound /e/ follows for the front vowels with F2 at 1958 Hz. For its height, /e/ is just below the 500 Hz mark at 424 Hz. This confirms that it is a mid-high front vowel as in the IPA chart.

The last among the front vowels /ɛ/ is slightly towards the centre of the chart with 1872 Hz for F2 and 498 Hz for F1. It qualifies to be taken as a mid-low front vowel. Just like other front vowels, this one is slightly higher than the corresponding mid-low back vowel /ɔ/.

4.1.1.2 Central vowel

Ekegusii has only one central vowel /a/. It is a low vowel as it records the highest F1 value of 622 Hz, which is the indicator for height. In terms of frontness or backness, that is F2, it records a mean figure of 1459 Hz. The vowel chart above shows it to be in the middle of all the other vowels. Note also that /a/ falls in the 1000-1500 Hz bloc like all the back vowels. This means that though it is a central vowel, it is skewed to the back and not accurately at the centre as it were.

4.1.1.4 Back vowels

There are three back vowels in Ekegusii, [ɔ, o,u]. The vowel /ɔ/ can be described as mid-low in terms of tongue height and back as regards the position of the tongue. With an F2 at 1302 Hz, this vowel is the one that is most skewed to the centre than the other two back vowels. F1 measures the tongue height. With an F1 of 537 Hz, /ɔ/ is slightly lower than the corresponding mid-low front vowel /ɛ/.

The vowel /o/ is the most back of the three back vowels. This sound had a F2 mean of 1081 Hz which was the lowest of them all. Later on, I will discuss another significance of F2 value for a vowel sound. F1 value carries the idea of vowel height and it can be seen here that /o/ records a mean of 451 Hz making it a mid-high vowel. It is observed to be slightly lower than the front counterpart /e/.

The last of the back vowels /u/ has an F2 mean of 1250 Hz which moves it slightly to the centre in comparison with /o/. In terms of height, that is F1 value, the vowel occupies the highest position among the back vowels at 352 Hz.

4.1.3 F2 and F3

The shape of the lips is an important way to classify vowel sounds. Lip rounding (or unrounding) is a way of modifying the vocal tubes as described by Fant (1960) for the source filter model. Different shapes of phonetic symbols have been used by phoneticians to display lip gestures. Sometimes the square symbol is used to indicate that the lips are unrounded or spread, while a circle is used to indicate that lips are rounded.

In many languages of the world, Ekegusii included, rounded vowels often are back vowels. For this particular case, we can see /ɔ, o, u/ as back vowels with varying F1 (height of the vowel), F2 (backness and roundedness of the vowel) and F3 (for lip roundedness). These signals for the lips can also be captured on the vowel trapezium which adds richness to the many ways of classifying a vowel (Mullany & Stockwell 2010: 60-4).

The third formant (F3) and the second formant (F2) are the ones that are directly related to lip rounding for vowels. In general, we describe the labial gesture as either unrounded (spread) and rounded. But behind this observable physical feature of the lips, there is a great deal of articulatory actions that go on during the production of a monophthong. The measurement of the third formant (F3) for any vowel can give direction on the extent of roundedness of a vowel or lack of it. For the front vowels, we will use F3, while for back vowels we will use F2 (Ladefoged 2001). The vowel sounds with low frequencies for F2 and F3 is indication of being rounded. Actual pictures taken of an informant during the articulation of the vowels can be able to visually display the state of the lips at that moment of production.

The following pictures taken of one of the female informants show the labial gesture for each of the seven Ekegusii vowels.

Figure 4.34: front and side picture of the lips for RF4 for /i/

This is how the lips are positioned during the articulation of vowel /i/. It is clear from it that the lower jaw comes very close to contacting the upper (static articulator) jaw. This is highest vowel in EkeGusii. The lips are also visibly spread or drawn apart. All these attributes give vowel sound /i/ the description of high, front, unrounded vowel.

Figure 4.35: front and side picture of the lips for /e/

The front and side pictures of the EkeGusii sound /e/ show a slightly lower drop of the jaw as compared to that of sound /i/. The tongue position has also changed slightly as it can be seen to have retracted a little bit. The pictures confirm that the vowel sound /e/ in EkeGusii is unrounded and mid high from the position of the jaw and tongue gesture.

Figure 4.36: front and side picture of the lips for /ɛ/

The above pictures show the front and side view of the mouth during the articulation of the vowel /ɛ/ by this female speaker. The vowel is visibly lower than the first two mentioned above and it is produced with spread lips. The jaw is visibly further dropped in comparison with the pictures for /e/. The tongue is also retracted as the lips are more spread.

Figure 4.37: front and side picture of the lips for /a/

These are the images of the mouth during the articulation of the central vowel /a/ in Ekegusii. The jaw is completely dropped and the tongue can be seen lumped up in the middle of the mouth. The lips are visibly apart indicating that it is spread. The picture indicates that vowel sound /a/ is the most open and lowest, from the jaw gesture, of all the Ekegusii vowels.

The remaining three back vowels are all rounded in various degrees.

Figure 4.38: front and side picture of the lips for /ɔ/

For the sound /ɔ/, the lips are drawn together to trace like a circle what is termed as roundedness. Both the front and side pictures can show that the corners of the mouth are drawn indicative of roundedness of the vowel. We can also peer into the oral cavity to notice that the tongue is retracted. The lower jaw is dropped but not as when articulating vowel sound /a/ as we saw above. This makes it mid low. The formant values will be used later on to qualify these impressionistic assertions.

Figure 4.39: front and side picture of the lips for /o/

For the vowel sound /o/ the lip corners are drawn closer and more compact than /ɔ/, hence in terms of degree of roundedness, /o/ is more rounded than /ɔ/. The jaw gesture also shows that the vowel is higher than /ɔ/ hence mid high. This vowel can be described to be a front, mid high, rounded vowel. This can also be corroborated by measuring the averages for the second formant F2 as we shall see later.

The last vowel among the rounded ones is /u/. This is the highest of the three back vowels as it can be seen on the pictures below.

Figure 4.40: front and side picture of the lips for /u/

Vowel sound /u/ is the most rounded of the three rounded Ekegusii vowels. The lip corners are close together forming a compact circle like figure. The tongue is pushed further back in the oral cavity as the jaw is raised. We can therefore describe the vowel as a back, high, rounded vowel. These photos can show various lip formations during vowel production. The Source–Filter Theory (Fant, 1960) describes it as tube modification to produce various vowel qualities. This can be confirmed by the group results for the second formant F2 that are relatively low.

Taking into account all the results, it will be prudent to show the result per group (we have males, females and children) as each group has its unique results that can be explained separately, before collapsing all of them into one.

The following are the averages for each of the three groups first and then the grand average that this research calls EkeGusii F2 and F3 formant features. The first on the line are males who typically have the lowest formant values due to the natural features of their vocal tract – longer and more muscular than those of females and children.

The following tables and charts give specific and general details for the results of informants for both F2 and F3 as relates to the lip roundedness, the lesser the value the more rounded the vowel. The following are the averages for F2-F3 for the males.

Table 4.27 F2-F3 average for males

Vowels	**F2**	**F3**
i	2148	**2789**
e	1988	**2588**
ɛ	1829	**2658**
a	1443	**2564**
ɔ	1253	**2419**
o	1173	**2455**
u	1253	**2293**

The F2 and F3 points for the males indicate higher frequencies for the front vowels /i/, /e/ and /ɛ/ and lower values for back vowels /ɔ/, /o/ and /u/ as expected. The Mean values for F2 and F3 can be plotted side by side as in the following plot.

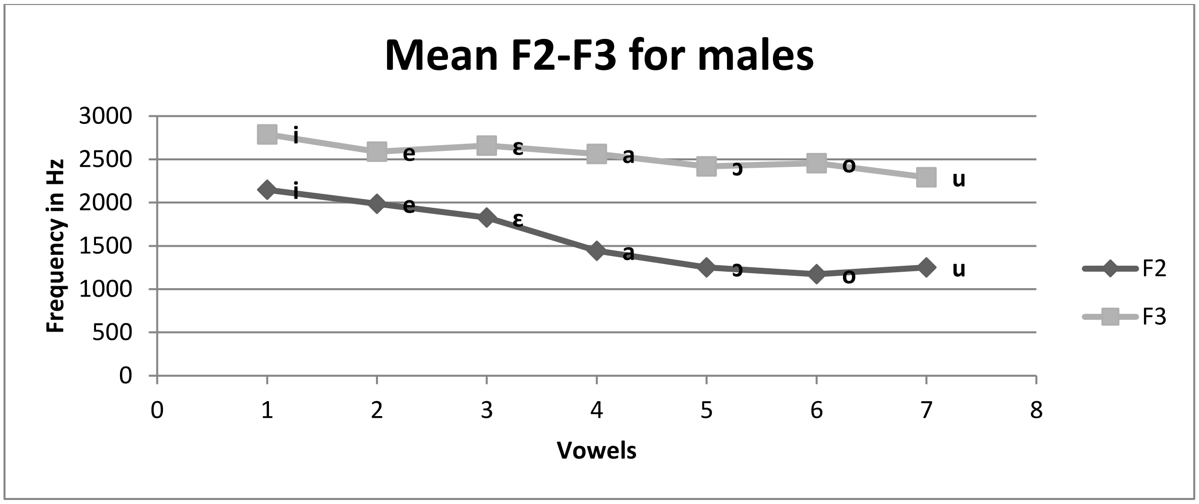


Figure 4.41: F2-F3 averages for men

The plots above show that the males had the three back vowels with low values for F2 and F3. /ɔ/ had a mean F2 of 1253 Hz and an F3 of 2419 Hz. /o/ was 2455 Hz for F3 and 1173 Hz for F2. /u had a mean of 2293 Hz for F3 and 1253 Hz for F2. The values indicate that for males, /o/ is the most rounded and backmost vowel followed by /u/ and /ɔ/. While all the back vowels had below 1300 Hz for F1, all the front vowels had above 1800 Hz for F1.

The following are the averages for the females F2 and F3.

Table 4.28 F2-F3 average for females

Females	F2	**F3**
i	2235	**3069**
e	1968	**2912**
ɛ	1968	**2962**
a	1745	**2829**
ɔ	1540	**2800**
o	1384	**2835**
u	1418	**2726**

The scatter plot that follows displays the contents in the above table in a better way.

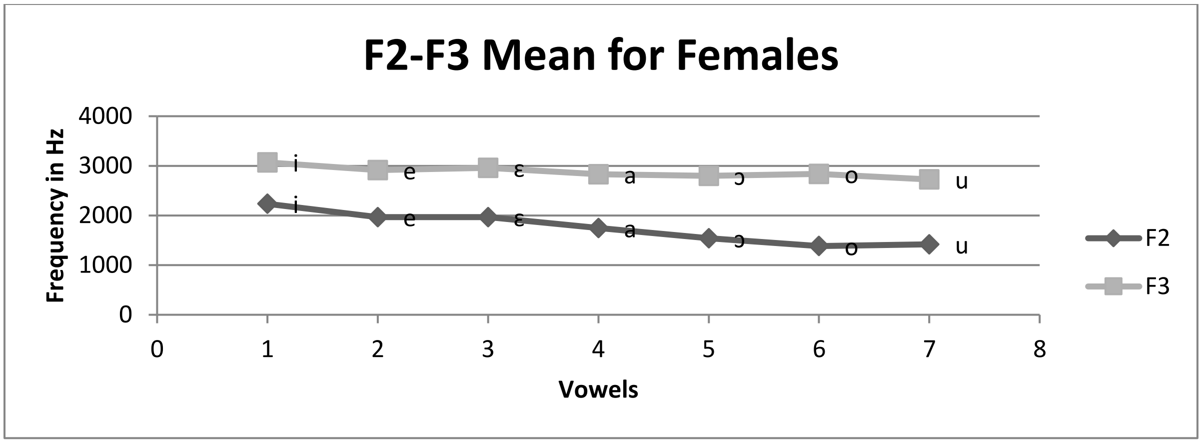


Figure 4.42: F2-F3 averages for females

Just like the males, the values for the front vowel are high and those of the back vowels are low. The frequencies for the females are, of course, higher than those of the males for all the seven vowels identified in Ekegusii.

/ɔ/ had 1540 Hz for F1 and 2800 Hz for F2. /o/ was 1384 Hz for F1 and 2835 Hz for F3 meaning that /o/ is the most rounded vowel for the females. /u/ was 1418 Hz for F1 and 2726 Hz for F2.

The following are the results for the children informants.

Table 4.29 F2-F3 average for children

Vowels	F2	**F3**
i	2390	**3428**
e	2235	**3256**
ɛ	2156	**3389**
a	1535	**2256**
ɔ	1295	**2943**
o	1365	**3233**
u	1331	**2867**

The table above was translated into the following scatter plot for better view.

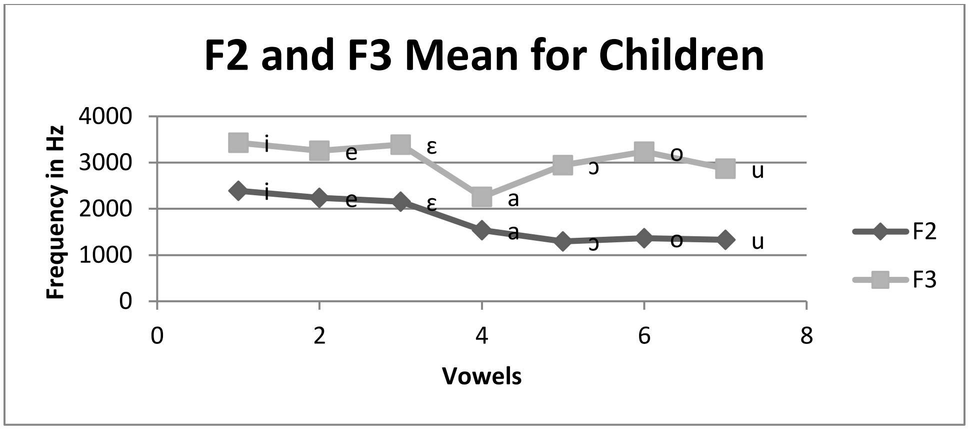


Figure 4.43: F2-F3 averages for children

The children had a mean F2 of 1295 Hz and an F3 of 2943 Hz which meeans that it was the most rounded vowel for the children informants. /o/ had an F2 mean of 1365 Hz and an F3 of 3233 Hz. /u/ was 1331 Hz for F2 and 2867 for F3.

There was a clear separation in values between the front vowels (which have high values) and the back vowels (which have lower values). /ɔ/ was 1362 Hz for F2 and 2721 Hz for F3. /o/ was 1307 Hz for F2 and 2841 Hz for F3. /u/ was 1334 Hz for F2 and 2629 Hz for F3. The values show that /o/ is the backmost and most rounded vowel.

When Chitest was carried out, the differences between the groups for both F2 and F3 had a p-value of less than five per cent ($p<0.05$) meaning that the differences were not random for these vowels but actually patterns discernable in the language.

Ladefoged (2001) points out that for front vowels; the degree of lip rounding is explained by F3. The round front vowels have lower frequency values. Ekegusii does not have any rounded front vowels and for that case we can see that the male's F2 averages for the front vowels /i, e, ɛ/ are high, that is, all have their frequency at above 1750 Hz (i 1766Hz, e 1831 Hz and ɛ 2026 Hz). The back vowels are known to be round since their F2 is low, that is, the lower the F2 the rounder the vowel. In this respect, the vowels /ɔ/ (1132 Hz), /o/ (1071 Hz) and /u/ (1124 Hz) with these low F2 values, can be confirmed to be rounded.

The formant values for females are slightly higher than those of the males for all the vowels for both F2 and F3. It is important to point out though that the general trajectory of the graphs is similar in shape indicating that the variations within vowels were also observed even in higher frequencies as witnessed for the females and children curves that came after the adult males which is expected due to sex and age influences. It can be seen that the front vowels have higher values than the central and back vowels.

The general, expected trend can be seen from the plot above. For Ekegusii, the focus is on F2 because only the back vowels are rounded. The back vowels here have lower frequencies as compared to the front vowels and the central vowel which is a confirmation of their roundedness. The averages for all the three groups together is as follows.

Table 4.30 F2-F3 average for group averages

Informants group means	i	e	ɛ	a	ɔ	o	u
MalesF2(Hz)	2148	1988	1829	1443	1253	1173	1253
F3(Hz)	2789	2534	2658	2564	2419	2455	2293
Fem F2(Hz)	2656	2203	2172	1343	1323	1189	1205
F3(Hz)	3134	2788	2828	1986	2648	2590	2615
ChildF2(Hz)	3001	2683	2164	1898	1398	1577	1222
F3(Hz)	3825	3648	3399	2788	2792	2692	2780

The front vowels are interesting to analyse here. The front most vowel /i/ does not record the highest F3 though. This means that in terms of openness, the vowel sound /e/ is the most open in Ekegusii, recording a mean of 2990 Hz. This is followed closely by vowel sound /ɛ/ which has an F3 mean of 2913 Hz.

In terms of roundedness, we consider the second formant F2. The lower the F2 the more rounded the vowel. On this chart, we can note that roundedness degree increases as we move from vowel number five to seven. Ekegusii vowel sound /u/ is the most rounded with an F2 mean at 1184 Hz. It is closely followed by /o/ which records 1279 Hz then /Ɛ/ with 1284 Hz. The three are the only rounded vowel in Ekegusii.

4.1.4 Vowel duration

Ladefoged and Disner (2012) state that each vowel in any given language has its unique duration measured in seconds. This duration depends on a number of factors that are context driven. It is also argued that the neighbouring sounds can, and may as we shall see later; determine the length of a vowel that they come into contact with in a word or in running speech. Furthermore, the number of syllables within a word may have a direct relation to the length of a vowel. This is also true with the position a vowel occupies within a word; the vowel on the first syllable will always tend to be longer and more intense than those of subsequent syllable(s) within a bi-syllabic or multi-syllabic word. For this reason, two syllable words were used as much as possible as a variable controller. This is even more necessary because vowel length is affected directly by the way a word or syllable ends.

Duration is an important element when analysing the vowels of Ekegusii or of any language for that matter. Vowel duration is phonemic EkeGusii. Apart from looking at spectrograms of any sound produced, the appropriate numbers of length are necessary for complete analysis. This can be very important, for example, when trying to create a computer speech synthesizer for a language since this works by setting a number of parameters like formants and duration. This is harder to get when we are dealing with running speech since it is hard to delineate all the rules that must be factored in so as to predict all the details of running speech.

Duration which is basically quantity of vowel is got by the time taken to produce a given segment. The good thing with any recording in Praat is that every recording is in relation to time. The times can be manipulated to the users' needs. It has been pointed out before that no one utterance is exactly the same as the next one even when produced by the same person. While analysing this data, one could easily notice the variations in the duration of vowels. Since each informant had to produce three tokens of any target vowel and then the average computed, one could not help but notice that the first word had the vowel longer than the second one which was equally slightly longer than the third one.

In each of the words, the first vowel sound was the one under focus and whose times were extracted and analyzed in order to control any intervening variables that may be context related in the CV syllable. The three words above are for the short vowel sound /i/. We can compare the object windows for the short and long vowel sound /i:/.

The object window shows that the target vowel sound /i:/ is longer just by the space it occupies on the window. The same procedure can be repeated for each of the words recorded.

The duration of each Ekegusii vowel was tracked in this research using data from words that were minimal pairs differing only in the perceived length differences. Where a minimal pair was not available in the required phonetic environment, a nonsense word was coined to fit the context. Also, data was elicited from carrier sentences.

It is commonplace to see formants of resonance normally attached at the end of vowel formants. This makes the vowel look longer than it actually is. This is usually the case with the final vowel, a distinctive feature in Ekegusii syllabification. To avoid this, analysis of the lengths of inter-consonantal vowels was done, those in the first syllable mainly. These resonance formants come up since the vocal tract is not closed immediately after the vocal fold vibration has ceased. This can be exemplified in the following waveform for the second male informant RM2.

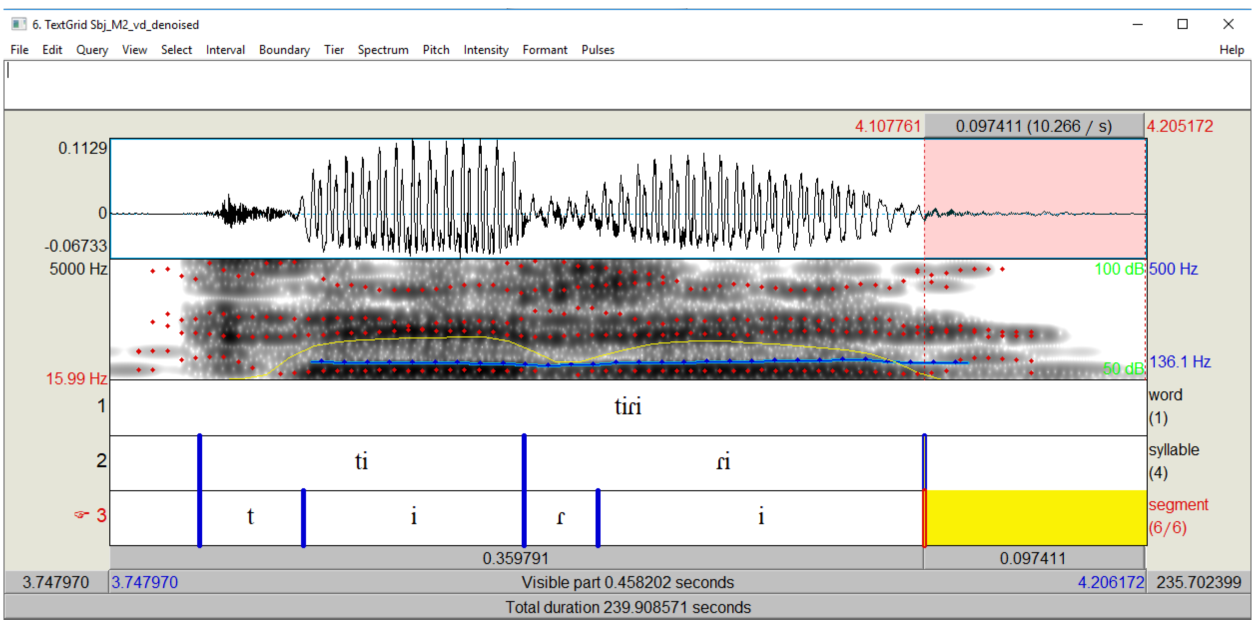


Figure 4.44: a vowel resonance

The part that is highlighted is the resonance tail for the final vowel /i/. Essentially, the vowel ended at the point where the red dot lines delineating the first and second formant change their steady trajectory and start to fall or disappear. One can always confirm it by listening in to that part by clicking on the rectangle below it that has the measurement of 97 milliseconds.

The following are the results for each vowel from all the informants whose voices were recorded for this research. The duration of the vowels was measured in milliseconds for uniformity. The summary of the recording for the first male informant, RM1, was as follows.

Table 4.31: average vowel durations for RM1

RM1 Vowel	**Short vowel Duration in Ms**	**Long vowel duration in Ms**
i	85	**169**
e	122	**157**
ɛ	81	**179**
a	83	**213**
ɔ	113	**199**
o	91	**167**
u	111	**152**

This male informant had a smaller range for both the short and long vowels. The range for the short vowels comes to 41 milliseconds, while the range for the short vowels is 61 milliseconds. The long vowels had a shorter length when compared to the lengths reported from the other informants for this study.

The following are the results for the second male informant for this study dubbed RM2 for the short and corresponding long vowels.

Table 4.32: average vowel durations for RM2

RM2 vowel	**Short vowel Duration**	**Long vowel duration**
i	81	252
e	81	246
ɛ	76	271
a	67	305
ɔ	93	285
o	70	190
u	79	178

The wordlist developed for this research, RM2 /i/ and /e/ recorded 81 Ms for the short vowel and 252 Ms and 246 Ms respectively; 76 Ms for the short vowel /ɛ/ and 271 Ms for the long vowel. The vowel sound /a/ had the shortest short vowel length of 67 Ms and the longest long vowel of 305 Ms. /ɔ/ had 93 Ms for the short vowel and 285 MS for the long vowel; /o/ recorded a mean of 70 Ms for the short vowel and 190 Ms for the long vowel. The vowel sound /u/ was 79 Ms for the short form and a mean of 178 Ms for the longer version.

The following table gives the summary for the third male informant MM3.

Table 4.33: average vowel durations for MM3

MM3 vowel	**Short vowel Duration**	**Long vowel duration**
i	70	334
e	77	277
ɛ	66	307
a	75	311
ɔ	77	308
o	69	339
u	52	230

The entries on the table above were used to plot the following bar graph which better displays the differences between the short and long vowels.

On this graph, we can see that the vowel /i/ for this speaker had duration of 70 Ms for the short vowel and 334 Ms for the long vowel. The mean for the vowel /e/ was 77 milliseconds for the short form and the long form was 277 milliseconds long. The last front vowel /ɛ/ has its short form at 66 milliseconds and 307 milliseconds for the long form. For the back vowels, /ɔ/ is approximately 77 milliseconds long for the short form and 308 milliseconds for the long for form. The next one is /o/ whose mean for the short form is 69 milliseconds and the long form was 339 milliseconds. The vowel /u/ also recorded the shortest duration for the short forms at 52 milliseconds for the short form and 230 milliseconds for the long form. The central vowel /a/ was 75 milliseconds for the short form and 311 milliseconds for the longer version.

The last male informant labelled MM4 had the following results extracted from his sound file for the duration of vowels.

Table 4.34: average vowel durations for MM4

MM4 vowels	**Short vowel Duration**	**Long vowel duration**
i	63	**217**
e	65	**283**
ɛ	78	**275**
a	70	**260**
ɔ	95	**338**
o	84	**295**
u	59	**293**

For MM4, /i/ was 63 milliseconds long and the long counterpart /i:/ was 217 milliseconds long. The short /e/ was 65 milliseconds long while the long /e:/ was 283 milliseconds long. The short mid-low vowel /ɛ/ was 78 milliseconds long and the long version /ɛ:/ was 275 milliseconds long. The central vowel /a/ had its short form average duration of 70 milliseconds and the long form at 260 milliseconds in length. The short /ɔ/ was 95 milliseconds long while its longer counterpart was 338 milliseconds long. The short /o/ had an average length of 84 milliseconds and the long /o:/ was 295 milliseconds long. Lastly, the short/u/ was 59 milliseconds long and the long form was 293 milliseconds long.

The range among the short vowels was 36 milliseconds (95-59) and the long vowels had a range of 121 milliseconds (338-217). The long vowel was seen to be three to five times longer than the shorter form hence making vowel duration phonemic in Ekegusii.

Tab. 4.35 a, and b shows the average duration of short and long vowels in Ekegusii for the male informants for this study.

Table 4.35a: Average short vowel durations for males

Vowel	RM1	**RM2**	MM3	**MM4**	Mean	**SD**
i	85	**81**	70	**63**	75	**9**
e	122	**81**	77	**65**	86	**21**
ɛ	81	**76**	66	**78**	75	**6**
a	83	**67**	75	**70**	74	**6**
ɔ	113	**93**	77	**95**	95	**13**
o	91	**70**	69	**84**	79	**9**
u	111	**79**	52	**59**	75	**23**

Table 4.35b: Average long vowel durations for males

Vowel	RM1	RM2	MM3	MM4	Mean	SD
i:	169	252	334	217	243	70
e:	157	246	277	283	241	58
ɛ:	179	271	307	275	258	55
a:	213	305	311	260	272	46
ɔ:	199	285	308	338	283	60
o:	167	190	339	295	248	82
u:	152	178	230	293	213	62

The average duration for the short vowel for males was under 100 milliseconds. The SD for the short vowel was small for the majority of the vowels but for /ɛ ɔ u/ they were obvious outliers with SDs 21, 13 and 23 respectively. The average range for the short vowels was 21 milliseconds.

For the long vowels as produced by males, all were above 200 milliseconds in length. The longest duration was recorded for the vowel /a/ and /u/ had the shortest duration. The average range for the long vowels for the males was 70 milliseconds. SD values ranged from 55-82 implying a greater dispersal from the mean as compared to the short vowels which had lesser SD values hence closely clustered together. There were no obvious outliers here.

The difference between the short vowel array and the long vowel array was statistically significant. On the T-test, the difference was $p<0.000001$. This very small figure means that the difference between the two sets of data was highly significant, that is, more than 99.999% that the data sets were different.

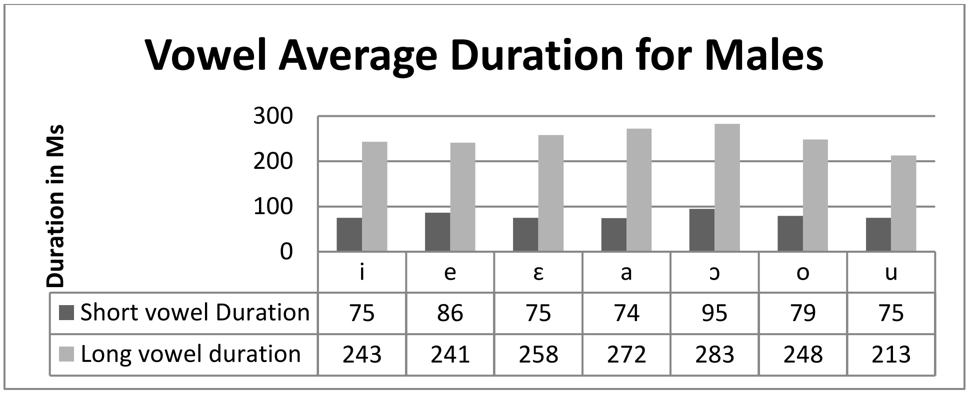


Figure 4.45: Long and short vowel durations for males

The group scores like the ones presented above can now be compared with those of other groups for this study. The average scores for males showed that the short vowel /i/ was 75 milliseconds while the long form /i:/ was 243 milliseconds in length. The short /e/ was 86 milliseconds and its longer counterpart /e:/ was 241 milliseconds long. /ɛ/ was 75 milliseconds and /ɛ:/ 258 milliseconds; /a/ was 74 milliseconds while /a:/ was 272 milliseconds long; /ɔ/ was 95 milliseconds long as /ɔ:/ had a mean of 283 milliseconds. /o/ settled at a mean of 79 milliseconds for the short vowel and the long one /o:/ was 248 milliseconds long. Lastly, /u/ was 75 milliseconds long and /u:/ was 213 milliseconds long.

Ekegusii has two distinct dialects and it was of interest to investigate the difference, if any, in the length of the vowels between Maate dialect and Rogoro dialects. Below are the durations of vowels for the speakers of the Rogoro dialect.

Table 4.36: Average short and long vowel durations for Rogoro dialect males

Vowels	Short	**Long**
i	83	**211**
e	102	**202**
ɛ	79	**225**
a	75	**259**
ɔ	103	**242**
o	81	**179**
u	95	**165**

The values on the table above were used to draw the following bar graph.

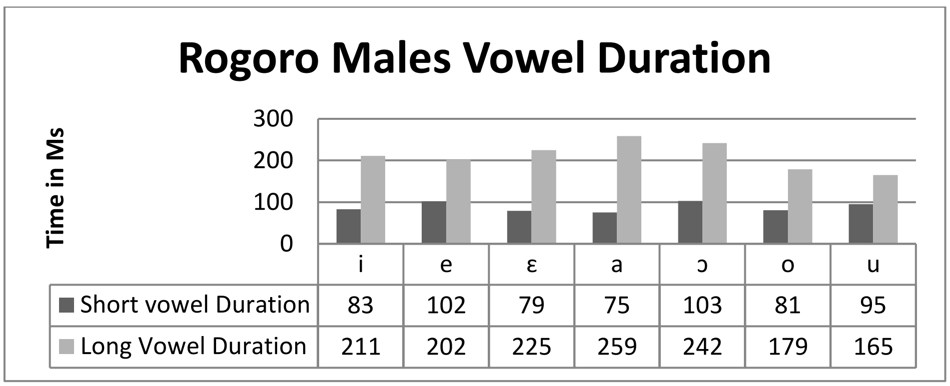


Figure 4.46: Long and short vowel durations for Rogoro dialect males

The adult male speakers of the Rogoro dialect recorded /i/ with 83 milliseconds and /i:/ had 211 milliseconds. /e/ had 102 milliseconds and /e:/had a length of 202 milliseconds. /ɛ/ was 79 milliseconds and the longer version was 225 milliseconds. The central vowel /a/ was 75 milliseconds for the short vowel and 259 milliseconds for the longer version. The short form of /ɔ/ was 103 milliseconds and the long form had a mean of 242 milliseconds. The short form of /o/ was 81 milliseconds long and the long form had a mean of 179 milliseconds. The last vowel /u/ had a mean of 95 milliseconds for the short form and 165 milliseconds for the long form.

The following table also has the data for the adult males who speak the Maate dialect.

Table 4.37: Average short and long vowel durations for Maate dialect males

Vowel	Short vowel duration in ms	**Long vowel Duration in ms**
i	67	**276**
e	71	**280**
ɛ	72	**291**
a	73	**286**
ɔ	86	**323**
o	77	**317**
u	56	**262**

The figures on the table above were used to come up with the following bar graph which better displays the variation between the long short vowels.

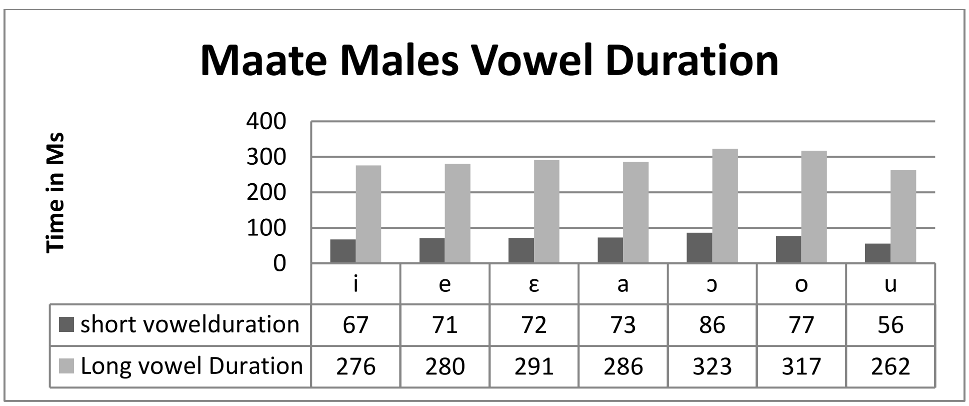


Figure 4.47: Long and short vowel durations for Maate dialect males

For the males who speak the Maate dialect, the vowel sound /i/ was 67 milliseconds for the short for and 276 milliseconds for the long form. /e/ was 71 milliseconds for the short form and 280 for the long version. The vowel sound /ɛ/ was 72 milliseconds for the short form and the long form was 291 milliseconds. The central vowel /a/ was 73 milliseconds for the short form and 286 milliseconds for the long form. The back vowel /ɔ/ was 86 milliseconds for its short form and 323 milliseconds for the long form, the longest average for the male informants. The other back vowel /o/ was 77 milliseconds for the short form and 317 milliseconds for the long form. The last back vowel is /u/ recorded a mean length of 56 milliseconds, the shortest span for the short vowel, and 262 milliseconds for the longer version.

The values reveal that that the two dialects had a significant variation between them. The Rogoro speakers had longer short vowel forms of averagely 88 milliseconds while the short vowel form for the speakers of the Maate dialect had an average of 72 milliseconds. A Student's test carried on these figures to find out whether the differences were significant showed that Maate dialect speakers had least average values for the short vowel with a significant difference of $p=0.01$. The long vowels had an even more significant number of $p=0.0004$. These figures imply that the vowel lengths for the two dialects could be discriminated by their respective quantities. This is a consistent pattern that is in the language and not just as a result of chance.

For the long vowels, the Maate dialect male informants had longer vowel lengths than the males who speak the Rogoro dialect. Using the Chi-test which compares the range of observed values with the expected values, we get the probability level of 0.01. This value is less than 0.05 ($p<0.05$) which means that the differences that are see between the vowel (long) lengths of the males who speak the Maate dialect and those who speak the Rogoro dialect were not just due to randomness, it was in fact a real pattern found in the population.

The following were the vowel duration results for females. The first female informant MW1 presented the following results.

Table 4.38: Average short and long vowel durations for MW1

MW1	short vowel duration in ms	long vowel duration in ms
i	66	**236**
e	97	**210**
ɛ	93	**189**
a	104	**266**
ɔ	115	**339**
o	114	**311**
u	84	**225**

The table above indicating the vowel lengths for MW1 was used to come up with the following bar graph that visually shows the difference between the short and long vowels.

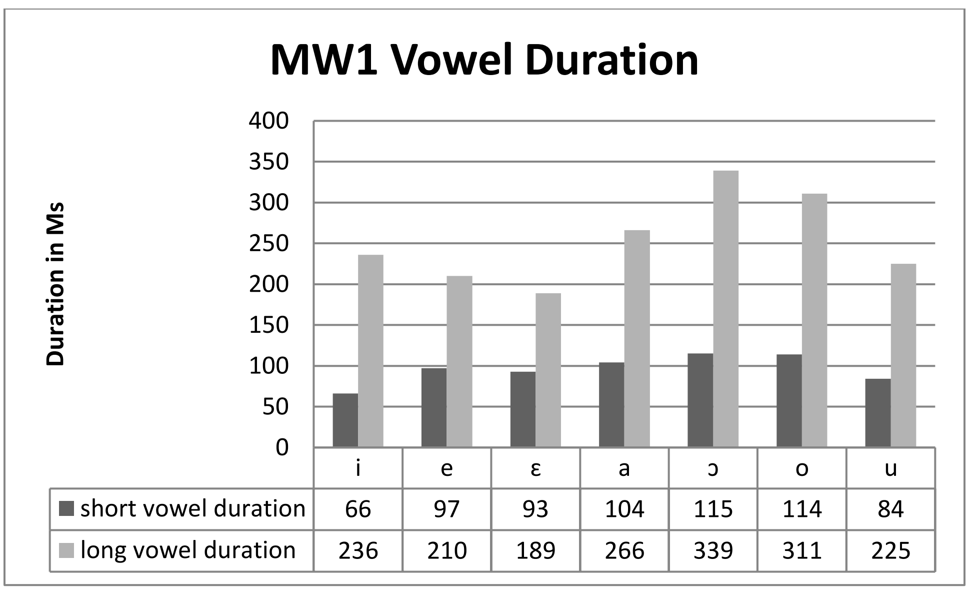


Figure 4.48: Long and short vowel durations for female informant MW1

For MW1, /i/ was 66 milliseconds for the short vowel and 236 milliseconds for the long counterpart. /e/ was 97 milliseconds for the short vowel and 210 milliseconds for the long version of the vowel. The vowel sound /ɛ/ for this informant was 93 milliseconds for the short form and 189 milliseconds for the long form of the vowel. The central vowel /a/ was 104 milliseconds for the short vowel and 266 milliseconds for the long form. /ɔ/ recorded a mean of 115 milliseconds for the short form and 339 milliseconds for the long form. The vowel /o/ was 114 milliseconds for the short form and 311 milliseconds for the long form. Finally, the vowel sound /u/ had a mean of 84 milliseconds for the short form and 225 milliseconds for the long form.

The following are the results for the second female informant labelled MW2.

Table 4.39: Average short and long vowel durations for MW2

MW2 vowels	**short vowel duration in ms**	**long vowel duration in ms**
i	90	186
e	88	201
ɛ	92	196
a	79	236
ɔ	112	342
o	102	270
u	74	245

The following bar graph was drawn from the above table.

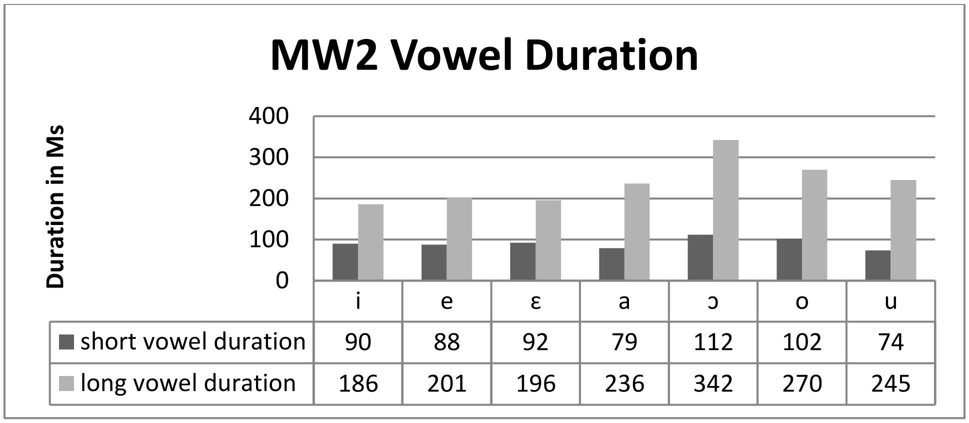


Figure 4.49: Long and short vowel durations for female informant MW2

The vowel /i/ had 90 milliseconds for the short form and 186 milliseconds for the long form. /e/ was 88 milliseconds for the short form and 201 milliseconds for the longer version of the vowel. The vowel /ɛ/ was 92 milliseconds for the short form and 196 milliseconds for the long form. The central vowel /a/ was 79 milliseconds for the short vowel form and 236 milliseconds for the long form. The back vowel /ɔ/ was 112 milliseconds for the short vowel and 342 milliseconds for the long vowel. The vowel sound /o/ was 102 milliseconds in its short form and 270 milliseconds for the long form. /u/ was 74 milliseconds for the short version and 245 milliseconds for the longer version of the vowel sound.

The third female informant labelled RW3 presented the following results for vowel sound lengths.

Table 4.40: Average short and long vowel durations for RW3

RW3 vowels	**short vowel duration in ms**	**long vowel duration in ms**
i	75	**243**
e	106	**334**
ɛ	118	**368**
a	110	**291**
ɔ	144	**378**
o	118	**275**
u	75	**276**

This table was used to come up with the following bar graph.

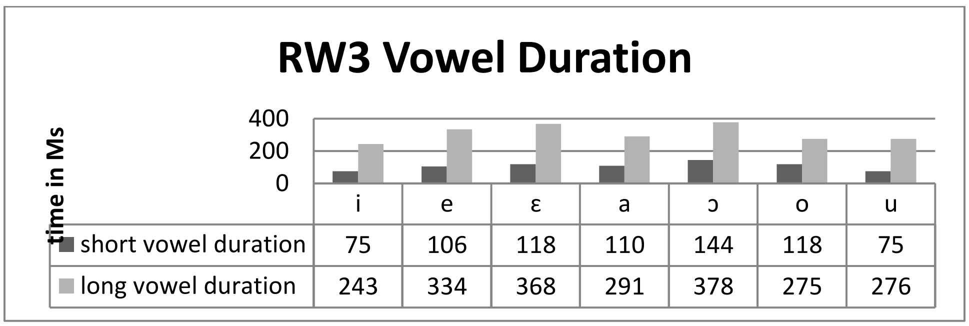


Figure 4.50: Long and short vowel durations for female informant RW3

For RW3, the vowel sound /i/ had a short vowel mean of 75 milliseconds and the long form was 243 milliseconds. The sound /e/ was 106 milliseconds for the short form and 334 milliseconds for the long form. The sound /ɛ/ was 118 milliseconds for the short form and 368 milliseconds for the long form. The sound /a/ had a mean of 110 for the short form and 291 milliseconds for the long form. For /ɔ/, the mean was 144 milliseconds for the shorter form and 378 milliseconds for the longer form. /o/ was 118 milliseconds for the shorter form and 275 milliseconds for the longer form. The sound /u/ was 75 milliseconds for the short form and 276 milliseconds for the longer version.

The last female informant was labelled RW4 and here are the durational results for each of the seven identified vowels.

Table 4.41: Average short and long vowel durations for RW4

RW4 vowels	short vowel duration in ms	long vowel duration in ms
i	73	**250**
e	71	**219**
ɛ	76	**305**
a	91	**190**
ɔ	92	**346**
o	86	**203**
u	84	**171**

This table gave forth the following bar graph for easy display of the short-long variation for the vowels.

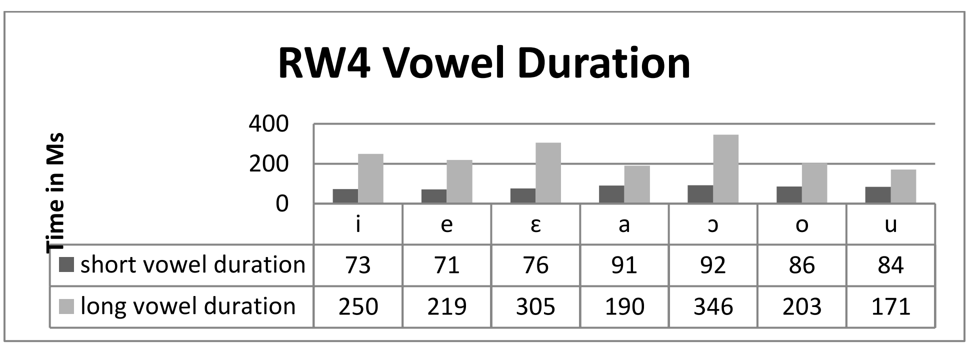


Figure 4.51: Long and short vowel durations for female informant RW4

This informant had the vowel /i/ recorded 73 milliseconds for the short form and 250 milliseconds for the long form. /e/ had 71 milliseconds for the shorter form and 219 milliseconds for the longer form. /ɛ/ was 76 milliseconds for the short form and 305 milliseconds for the long form. The central vowel /a/ had a short form of 91 milliseconds and the long counterpart was 190 milliseconds. The vowel /ɔ/ was 92 milliseconds for the short form and 396 milliseconds for the long form. /o/ was 86 milliseconds for the short form and 203 milliseconds for the long form. Lastly, /u/ was 84 milliseconds for the short form and 171 milliseconds for the long counterpart.

The following are the average vowel length means for the females.

Table 4.42a: Average short vowel durations for females

Vowels	MW1	**MW2**	RW3	**RW4**	AVERAGE	**SD**
i	66	**90**	75	**73**	76	**10**
e	97	**88**	106	**71**	91	**15**
ɛ	93	**92**	118	**76**	95	**17**
a	104	**79**	110	**91**	96	**14**
ɔ	115	**112**	144	**92**	116	**21**
o	114	**102**	118	**86**	105	**14**
u	84	**74**	75	**84**	79	**6**

Table 4.42b: Average short vowel durations for females

Vowels	MW1	**MW2**	RW3	**RW4**	AVERAGE	**SD**
i	236	**186**	**243**	**250**	229	**29**
e	210	**201**	334	**219**	241	**62**
ɛ	189	**196**	368	**305**	265	**87**
a	266	**236**	291	**190**	246	**43**
ɔ	339	**342**	378	**346**	351	**18**
o	311	**270**	275	**203**	265	**45**
u	225	**245**	276	**171**	229	**44**

The bar graph out of the above values is as Fig. 4.52.

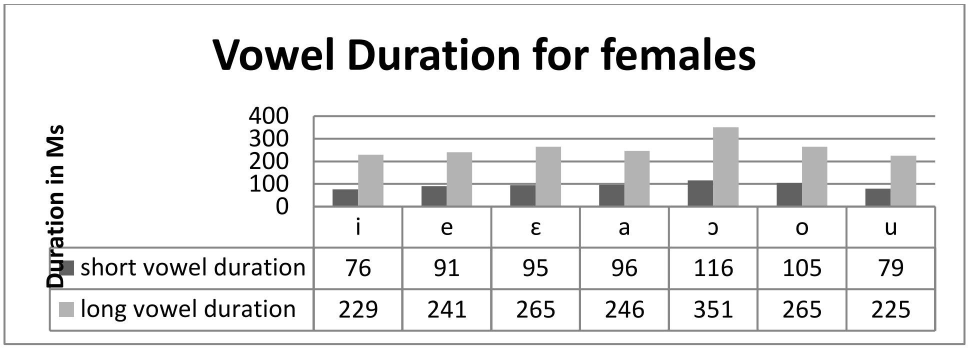


Figure 4.52: Long and short vowel durations for female informants

The females had a mean of 76 milliseconds for /i/ and 229 milliseconds for /i:/. The vowel sound /e/ had a mean of 91 milliseconds for the short version and 241milliseconds for the longer version. /ɛ/ had 95 milliseconds for the short form and 265 milliseconds for the long form. /a/ was 96 milliseconds for the long form and 246 milliseconds for the long. /ɔ/ was 116 milliseconds for the short vowel and 351 milliseconds for the long vowel. /o/ was 105 milliseconds for the short form and 265 milliseconds for the longer version. Lastly, /u/ had a short form of 79 milliseconds for the short form and 225 milliseconds for the longer version.

The females who speak Rogoro dialect had the following mean vowel durations. Fig. 4.53 is a graphical display for the Rogoro dialect females.

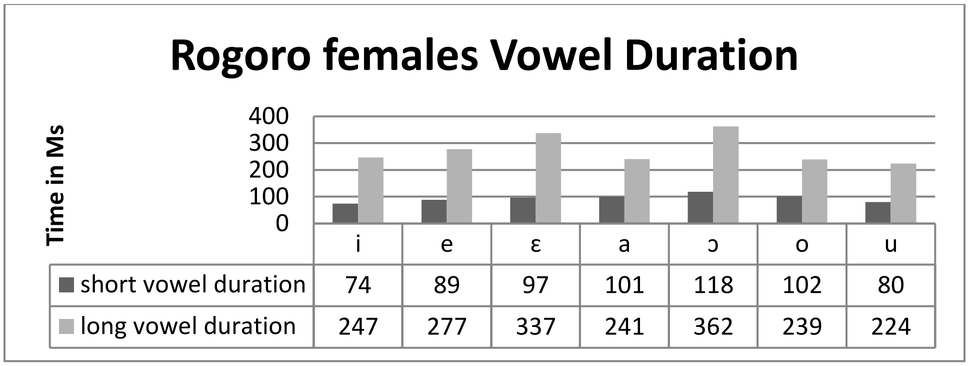


Figure 4.53: Long and short vowel durations for Rogoro dialect females

The general quantity of each vowel sound and its long counterpart for female speakers of Rogoro dialect was not far removed from females' averages as a whole. We can compare this with female speakers of Maate dialect as follows.

Table 4.43: Average short and long vowel durations for Maate dialect female

Vowels	**short vowel duration in ms**	**long vowel duration in ms**
i	78	211
e	93	206
ɛ	93	193
a	92	251
ɔ	114	341
o	108	291
u	79	235

The values in the above table were used to draw the following bar graph for the females who speak the Maate dialect.

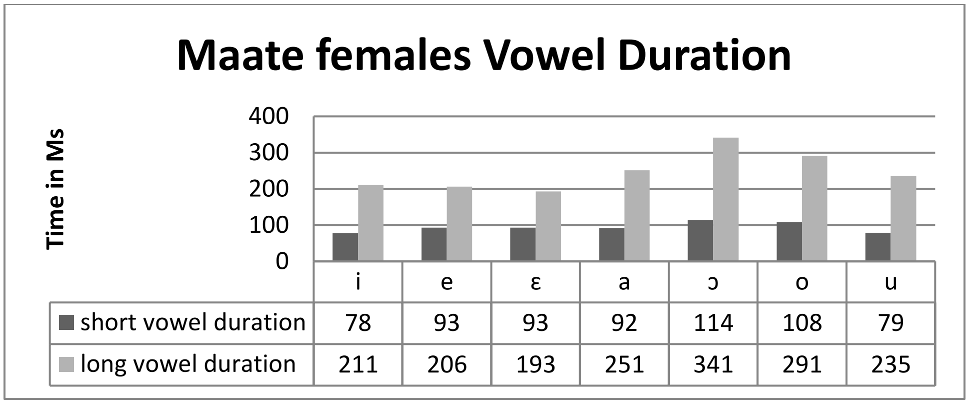


Figure 4.54: Long and short vowel durations for Maate dialect females

The same trend was observed for Maate dialect speakers with some variation between them. A Chi-test carried on the values to investigate the difference between the actual values got from females who speak Rogoro dialect and those who speak Maate dialect and the expected values indicated p-values that were greater than 0.05 ($p>0.05$). This means that the variations were negligible and that the differences were just random and not a real pattern that is attributable to the population.

The following are the vowel average durations for children.

Table 4.44: Average short and long vowel durations for children

Children vowels	**Short vowel in ms**	**Long Vowel in ms**
i	91	**276**
e	98	**263**
ɛ	97	**265**
a	85	**228**
ɔ	92	**272**
o	91	**239**
u	85	**231**

This table can be translated into the following bar graph.

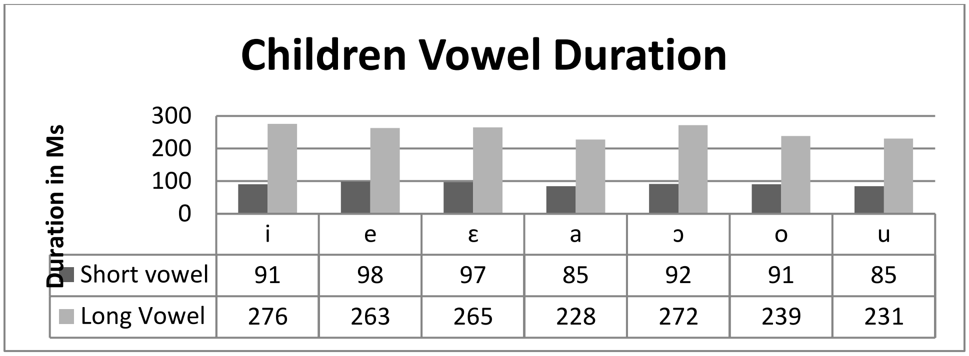


Figure 4.55: Long and short vowel durations for children

The children had a mean of 91 milliseconds for the short vowel /i/ and 276 milliseconds for the long counterpart. /e/ had a mean of 98 milliseconds for the short form and 263 milliseconds for the long form. /ɛ/ had a mean of 97 milliseconds for the short form and 265 milliseconds for the long form. The central vowel /a/ was 85 milliseconds for the short form and 228 milliseconds for the longer counterpart.

For the back vowels, /ɔ/ had a short form of 92 milliseconds and the long form was 272 milliseconds. /o/ was 91 milliseconds for the short form and 239 milliseconds for the long form. Lastly, /u/ had a short form of 85 milliseconds and the long form was 231 milliseconds.

Concerning the dialectal difference between them, those who speak the Rogoro dialect presented the following results.

Table 4.45: Average short and long vowel durations for Rogoro dialect children

vowel	Short Vowel in ms	**Long Vowel in ms**
i	97	**269**
e	103	**297**
ɛ	101	**254**
a	91	**248**
ɔ	100	**308**
o	94	**237**
u	83	**234**

The following bar graph was drawn from the values on the table above.

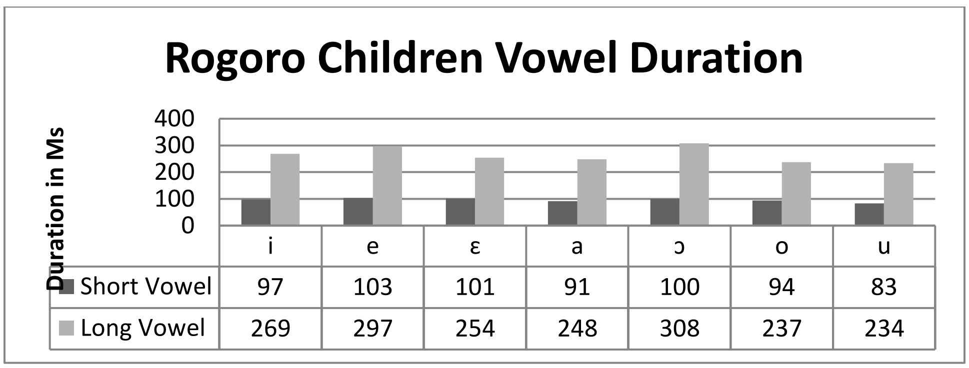


Figure 4.56: Long and short vowel durations for Rogoro dialect children

The children who speak the Rogoro dialect posted a mean of 97 milliseconds for /i/ and 269 milliseconds for /i:/. /e/ was 103 milliseconds for the short vowel and 297 milliseconds for the long counterpart. /ɛ/ was 101 milliseconds for the short form and 254 milliseconds for the long form. The central vowel /a/ was 91 milliseconds for the short form and 248 milliseconds for the long version. /ɔ/ had the short form at 100 milliseconds and the long form was 308 milliseconds. /o/ had a short form mean of 94 milliseconds and the long form was 237 milliseconds. Lastly /u/ was 83 milliseconds for the short form and 234 milliseconds for the long counterpart.

For the children who speak the Maate dialect, the table below bears the vowel duration results.

Table 4.46: Average short and long vowel durations for Maate dialect children

Vowels	Short vowels in ms	**Long vowels in ms**
i	84	**282**
e	93	**229**
ɛ	93	**278**
a	80	**209**
ɔ	85	**236**
o	89	**242**
u	88	**228**

Tab. 4.57 is a bar graph for the children who speak the Maate dialect.

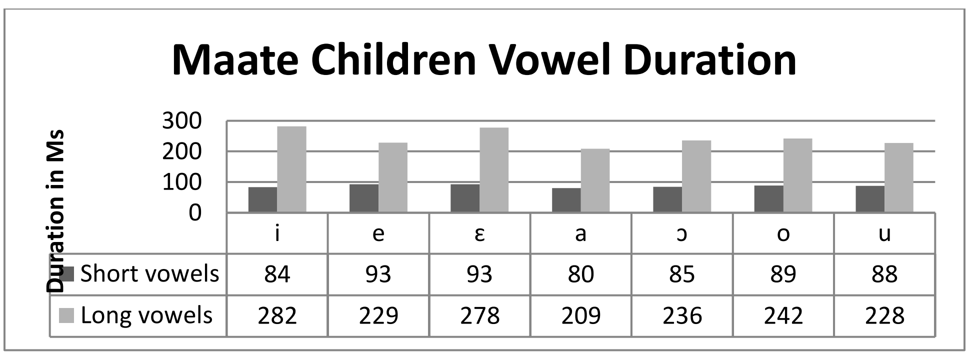


Figure 4.57: Long and short vowel durations for Maate dialect children

The duration for /i/ for the children who speak the Maate dialect was 84 milliseconds for the short vowel and 282 milliseconds for the long form. The short /e/ was 93 milliseconds as the long form was 278 milliseconds. /ɛ/ had a short form of 93 milliseconds and the long form was 278 milliseconds. /a/ had 80 milliseconds for the short form and 209 milliseconds for the long form. /ɔ/ had 85 milliseconds for the short vowel and 236 milliseconds for the long form. /o/ was

89 milliseconds for the short form and 242 milliseconds for the longer version. /u/ was 88 milliseconds for the short form and 228 milliseconds for the long form.

The Chi-test results for the vowel lengths of the two dialects of EkeGusii as got from children informants yielded a difference p-value that was higher than five percent ($p>0.05$) for both the long and short vowel forms. T-test values reveal that the short vowel forms were significantly different with a p-value of 0.01. Long vowels were not significantly different as seen by a p-value of 0.08. Therefore, the differences between the long vowel sound lengths between the dialects were random and could not be attributed to a pattern in the language.

4.1.5 Discriminant analysis

4.1.5.1 Results on discriminant analysis using F0, F1, F2 andF3

Results on discriminant analysis using F0 indicate that F0 makes no significant contribution as the F0 values in each of the three groups are very close. In structure matrix, the pooled within-within group's correlations between discriminating variables and standardized canonical discriminant functions give the following order as seen on Tab. 4.47.

Table 4.47: structure matrix for discriminant values for F0, F1, F2 and F3 for all subjects

	Function			
	1	2	3	4
f2	.582	.663*	.470	-.041
f1	-.622	.658*	.241	.348
f3	.150	.048	.987*	.020
f0	.028	-.021	.277	.960*

From the table we can deduce that F2 posits the largest absolute correlation considering each variable for its discriminant function. F2 is followed by F1 then F3 and the least contributor is

F0. The Wilk's Lambda score for all the variables is highly significant at $p<.0001$. F1, F2, and F3 were together very discriminating with a high significance of 0.0001. For F2 and F3, the results showed a not very significant value of 0.644 and for F3 alone it was 0.917.

Tab. 4.48 gives the discriminant analysis for each vowel and the overall discriminant contribution of each vowel.

vowels			**Predicted Group Membership**							**Total**
			i	e	ɛ	a	ɔ	o	u	
Original	Count	i	9	3	0	0	0	0	0	12
		e	3	8	1	0	0	0	0	12
		ɛ	0	0	12	0	0	0	0	12
		a	0	0	0	9	3	0	0	12
		ɔ	0	0	0	0	11	1	0	12
		o	0	0	0	0	2	8	2	12
		u		1	0	0	0	2	9	12
	%	1.00	75.0	25.0	0.0	0.0	0.0	0.0	0.0	100.0
		2.00	25.0	66.7	8.3	0.0	0.0	0.0	0.0	100.0
		3.00	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0
		4.00	0.0	0.0	0.0	75.0	25.0	0.0	0.0	100.0
		5.00	0.0	0.0	0.0	0.0	91.7	8.3	0.0	100.0
		6.00	0.0	0.0	0.0	0.0	16.7	66.7	16.7	100.0
		7.00	0.0	8.3	0.0	0.0	0.0	16.7	75.0	100.0
Cross-validated	Count	1.00	8	3	0	0	0	0	1	12
		2.00	3	7	1	0	0	0	1	12
		3.00	0	1	10	0	0	0	1	12
		4.00	0	0	0	9	3	0	0	12
		5.00	0	0	0	0	9	3	0	12
		6.00	0	0	0	0	3	7	2	12
		7.00	0	1	0	0	0	2	9	12
	%	1.00	66.7	25.0	0.0	0.0	0.0	0.0	8.3	100.0
		2.00	25.0	58.3	8.3	0.0	0.0	0.0	8.3	100.0
		3.00	0.0	8.3	83.3	0.0	0.0	0.0	8.3	100.0
		4.00	0.0	0.0	0.0	75.0	25.0	0.0	0.0	100.0
		5.00	0.0	0.0	0.0	0.0	75.0	25.0	0.0	100.0
		6.00	0.0	0.0	0.0	0.0	25.0	58.3	16.7	100.0
		7.00	0.0	8.3	0.0	0.0	0.0	16.7	75.0	100.0

General results on discriminant analysis using F1 and F2 values show that they had significant contribution to the difference in variance with a $p<.0001$ for the Wilk’s Lambda. 78.6% of the original grouped cases were correctly classified by F1 and F2 while 70.2% of cross-validated grouped cases were correctly classified. The result for this one was higher than that reported by Hillenbrand et al. (1995) at 68.2% and the one by Peterson and Barney (1952) at 74.9%. EkeGusii vowel /ɛ/ had the highest classification rate of 100% while /e/ had the lowest classification of 66.7%.

4.1.5.1 Results on discriminant analysis by gender

Classification of results by gender increased the rate of correct classification. Males had 96.4% of original group cases correctly classified. Tab 4.49 gives outcome of the effect of gender on classifying the vowels of Ekegusii. This was done for adult informants only since children informants reduced the classification to 50%. This indicates that it is difficult to correctly predict and discriminate the gender of children using acoustic cues. This was expected as the informants were all 8 years old, a time before any secondary sexual characteristics, which also affect voice quality, set in.

Table 4.49 Discriminant results on predicting group membership by gender

gender			Predicted Group Membership		Total
			.00	1.00	
Original	Count	.00	27	1	28
		1.00	0	28	28
	%	.00	96.4	3.6	100.0
		1.00	0.0	100.0	100.0

For the females, 100% of original grouped cases were correctly classified. This means that gender was a high classifier at 98.2% of all grouped cases were correctly classified. The results indicate that values for F1 and F2 can be used to discriminate between the genders by 98 %. F3 was the poorest classifier. These results are confirmed by Wilk's Lambda testas in Tab. 50 below.

Table 50: Wilk's Lambda test of functions for adult speakers

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 3	.047	110.307	18	.000
2 through 3	.276	46.383	10	.000
3	.892	4.101	4	.393

Tab. 50 shows F1, F2 and F3 test results with F1 and F2 having highly significant values of p<0.0001 while F3 was not significant with p=0.393. This means that the values for F1 and F2 are highly discriminative as to be used to discriminate between the genders unlike F3 values.

The same trend is seen on Tab 51 for all 12 speakers, that is, adding children.

Table 51: Wilk's Lambda test of functions for all speakers

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 3	.026	132.041	18	.000
2 through 3	.196	58.577	10	.000
3	.869	5.043	4	.283

The significance value for F1 and F2 remain at p<0.0001 while that of F3 is still not significant at p=0.283.

When we have all the speakers' results, that is, men, women and children, the discriminant function reduce considerably by gender. Tab. 52 gives the classification results for all informants.

Table 52: Classification results of EkeGusii vowels using F1, F2 and F3 values for all speakers

			vowels	Predicted Group Membership							Total
				i	e	ɛ	A	ɔ	o	u	
Cases Selected	Original	Count	i	3	1	0	0	0	0	0	4
			e	1	3	0	0	0	0	0	4
			ɛ	0	0	4	0	0	0	0	4
			a	0	0	0	4	0	0	0	4
			ɔ	0	0	0	0	3	0	1	4
			o	0	0	0	0	1	3	0	4
			u	0	0	0	0	0	0	4	4
		%	i	75.0	25.0	.0	.0	.0	.0	.0	100.0
			e	25.0	75.0	.0	.0	.0	.0	.0	100.0
			ɛ	.0	.0	100.0	.0	.0	.0	.0	100.0
			a	.0	.0	.0	100.0	.0	.0	.0	100.0
			ɔ	.0	.0	.0	.0	75.0	.0	25.0	100.0
			o	.0	.0	.0	.0	25.0	75.0	.0	100.0
			u	.0	.0	.0	.0	.0	.0	100.0	100.0
Cases Not Selected	Original	Count	i	3	1	0	0	0	0	0	4
			e	0	0	4	0	0	0	0	4
			ɛ	0	0	4	0	0	0	0	4
			a	0	0	1	3	0	0	0	4
			ɔ	0	0	0	3	1	0	0	4
			o	0	0	0	0	3	1	0	4
			u	0	0	0	0	1	2	1	4
		%	i	75.0	25.0	.0	.0	.0	.0	.0	100.0
			e	.0	.0	100.0	.0	.0	.0	.0	100.0
			ɛ	.0	.0	100.0	.0	.0	.0	.0	100.0
			a	.0	.0	25.0	75.0	.0	.0	.0	100.0
			ɔ	.0	.0	.0	75.0	25.0	.0	.0	100.0
			o	.0	.0	.0	.0	75.0	25.0	.0	100.0
			u	.0	.0	.0	.0	25.0	50.0	25.0	100.0

As seen on Tab. 52, all speakers reduce the selected original grouped cases correct classification to 69%. This was down from 87.5% for adults alone. The results imply that for children alone, F1, F2 and F3 values cannot correctly discriminate between the genders. That notwithstanding, 72.2% of unselected original grouped cases were correctly classified. Only 57.1% of the original selected cases for children informants were correctly classified as either male or female as opposed to 87.5% for the adult informants. Cross validation is done only for those cases in the analysis where each case is classified by functions derived from all cases other than that case. For the children, 53.6% of cross-validated grouped cases were correctly classified. What these results mean is that it is just very difficult to discriminate between the sexes by looking at the formant results for children while for adults, the difference between the sex shows very high classification rates. For children, the best explanation is that by age 8, male vs. female speech features, due to the growth of secondary sex characteristics, have not been realized, the more reason for difficulty in discrimination.

4.2 EkeGusii stop consonants

There are three stop consonants in EkeGusii. These are the bilabial plosive /p/; alveolar plosive /t/, and velar plosive /k/ (Cammenga 2002, Otieno 2013). Just like all other consonants, we cannot classify stop consonants on the basis of a well-defined formant pattern. We have to take into account to such qualities as voicing, noise frequencies, formant transitions and even portions of silence. Plosives typically involve a portion of silence that is associated with occlusion and friction of noise that comes with release of closure. This burst is characterized by high frequencies. Several qualities of stop consonants can be measured to give cue to a plosive like duration, voice onset time (VOT), burst intensity, fundamental frequency after stop consonant, and second formant transition after plosive. Place of articulation is cued by spectral patterns of release bursts.

The recorded data for this research, both from the word lists and carrier sentences, was sampled at 44100 Hz in a 16-bit quantization. For band noise base, this work set it at 20 Hz meaning that frequencies above 20 Hz could not be utilized.

To answer the second research question in section 1.4 above, the following measurements were taken: a) Duration measurements: total stop consonant duration, closure duration, voice onset time, burst duration and intensity rise time of the following vowel following stops, b) Intensity measurements: RMS intensity of the stop burst, relative intensity, c) coarticulation: F2 at onset and middle of the vowel following a stop.

All the duration measurements were made using Praat version 6.0.32 (Boersma & Weenink 2017).

4.2.1 Duration measurement results

4.2.1.1 Stop closure duration

Stop closure duration was measured from the offset of the previous vowel to the onset of the burst on the spectrogram. This measurement could only be made when the stop consonant appeared at the intervocalic position in word lists and both word initial and word medial in carrier sentences. Time domain was given to be in milliseconds.

Ekegusii stop consonants /p, t, k/ are all said to be voiceless from the literatures and, therefore, their closure duration is a lapse of silence, save maybe for the very low frequency background noise or residue preceding vowel resonances. The biggest task here was to get the exact point of the preceding vowel offset and burst of the stop. After establishing these two points that define stop closure duration, there was still some clicking that was heard once the part selected was played. This was resolved by clicking select button on the edit menu and pick on 'move start of selection to the nearest zero crossing' for the left side. The same was done to the right side by clicking 'move end of selection to the nearest zero crossing' as in Fig. 4.58 on closure duration for the voiceless bilabial stop consonant /p/ produced by male informant (RM2) with highlighted area in a pink hue designating the closure part of the stop /p/.

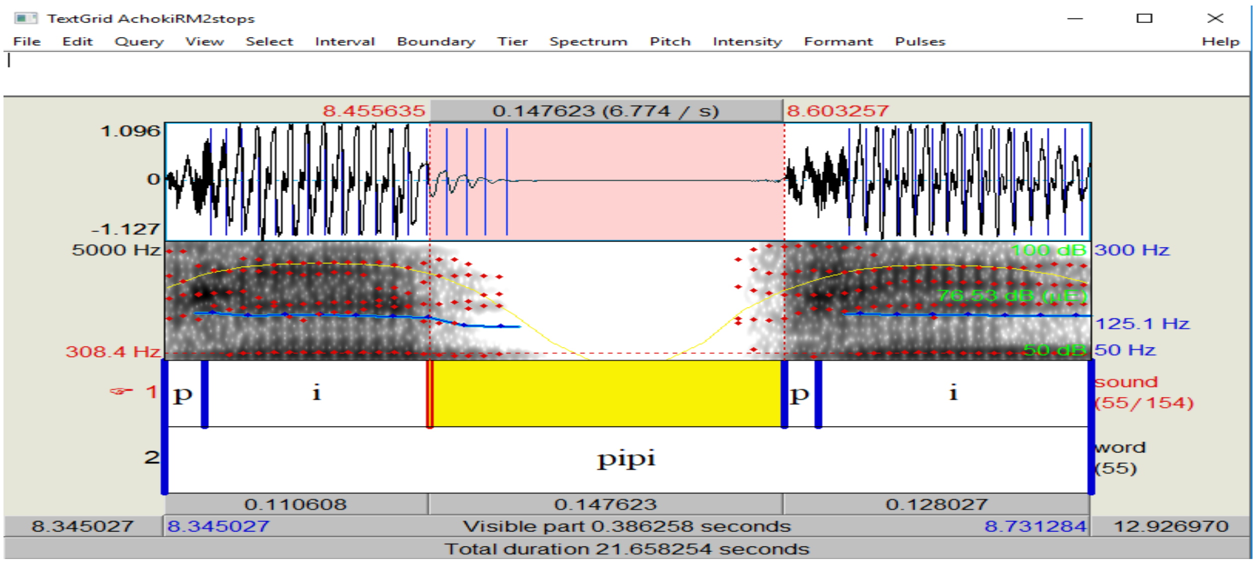


Figure 4.58: waveform and spectrogram for the closure duration of /p/ for RM2

Taking the above mentioned steps gave starting time, ending time and crucially closure duration which is visible above by two vertical, pink lines.

Plosive qualities measured and described here were those that were at intervocalic position as initial plosives in citation form could not be measured for closure duration. Three lexical items were assigned to each plosive in the environment of three select vowels as: *pi**pi**pi*, *pa**pa**pa*, *po**po**po*, *ti**ti**ti*, ***ata**ta*, *o**to**to*, ***iki**ki*, ***aka**ka*, *o**ko**ko*. The plosive and vowels in bold were the ones under analysis as they were at word medial position.

4.2.1.1.1 Closure duration for /p/

Closure duration for voiceless bilabial stop consonant /p/was measured when it came after vowels /i, a, o/ standing for front, low and backmost vowels respectively, to see the effect of the vowel on closure duration. Result from various vowel environments were summarised into mean values and for groups created in this study for easy processing and presentation.

The following are the results for adult female informants for this study.

Table 4.50: closure duration average for /p/ for adult female informants

Subjects	pi	pa	po	Mean	SD
MW1	110	113	113	112	2
MW2	87	87	92	89	3
RW3	155	134	151	147	11
RW4	109	101	99	103	5
Mean	115	109	114	113	3
SD	29	20	26	25	4

Adult female informants for this study had a general mean of 115 milliseconds for the stop consonant /p/ at intervocalic position when with /i/. Closure duration for /p/ was averagely 109 milliseconds in the environment of /a/ and 114 milliseconds in the environment for /o/. The range produced here by the means was 4 milliseconds with fairly small standard deviations of 29 for /pi/, and 20 for /pa/ and 26 for /po/.

Significance test on the difference between the scores for /pi/, /pa/ and /po/ all yielded p-values of $p>0.05$ meaning the difference was not significant being above the $p<0.05$ threshold. Significant differences were noted between speakers of the two dialects, Rogoro and Maate. The female speakers of Maate dialect presented the following results.

Table 4.51: closure duration average for /p/ for Maate dialect female informants

speaker	pi	pa	po	Mean	SD
MW1	110	113	113	112	2
MW2	87	87	92	89	3
Mean	99	100	103	100	2
SD	16	18	15	16	2

The results indicate average closure duration for /p/ to be 100 milliseconds for the females who speak the Maate dialect of EkeGusii. We can compare these results with those who speak the Rogoro dialect as follows.

Table 4.52: closure duration average for /p/ for Rogoro dialect female informants

speaker	pi	pa	po	Mean	SD
RW3	155	134	151	147	11
RW4	109	101	99	103	5
Mean	132	118	125	125	7
SD	33	23	37	31	7

The differences between the two dialects of EkeGusii were significant, that is, p=0.03. This implied that there was more than 97% chance that the differences recorded between the two dialects were not as a result of random chance but a consistent, predictable pattern in the language. That, the Rogoro adult female speakers had consistently longer closure duration for the stop consonant /p/ as compared to those speakers of EkeMaate dialect of Ekegusii.

The following are the closure duration results for /p/ for the adult male speakers.

Table 4.53: closure duration averages for /p/ for adult male informants

speakers	pi	pa	po	Mean	SD
RM1	120	134	131	128	7
RM2	143	165	141	150	13
MM3	64	88	94	82	16
MM4	85	92	104	94	10
Mean	103	120	118	113	9
SD	35	37	22	31	8

With a range of 68 milliseconds, average closure duration for the stop consonant /p/ is 113 milliseconds. A low standard deviation of 9 indicated that the values for each environment were not very much dispersed from the mean as the values of adult females who had a standard deviation of 3.

While the averages capture the group values, there were differences from one informant to another. Two significant outliers are RM2 with consistent high values and MM3 with the lowest values for the three instances of /p/ under focus.

Another notable difference was between the males who speak the Maate and Rogoro dialect. The following are the results for the two groups of males who speak the Rogoro or Maate dialect.

Table 4.54: closure duration average for /p/ for Rogoro dialect adult male informants

Speakers	pi	pa	po	Mean	SD
RM1	120	134	131	128	7
RM2	143	165	141	150	13
Mean	132	150	136	139	9
SD	16	22	7	15	7

The average range for the Rogoro dialect males was 18 milliseconds and an average of 139 milliseconds. This was consistently higher than those recorded for the Maate counterparts. The values above were compared to those of the Maate dialect as Tab. 4.55 shows below.

Table 4.55: closure duration average for /p/ for Maate dialect adult male informants

speakers	pi	pa	po	Mean	SD
MM3	64	88	94	82	16
MM4	85	92	104	94	10
Mean	75	90	99	88	12
SD	15	3	7	8	6

Average closure duration for male speakers of Maate dialect was 88 milliseconds with an average range of 24 milliseconds. Just like the females, Rogoro dialect males of EkeGusii recorded higher values for the closure duration of /p/. A T-test carried out to tell the significance of the difference between them yielded p=0.001. This was a very high significance rate meaning that the differences were a recognizable pattern in the language that the Rogoro dialect speakers of EkeGusii had long closure duration than their Maate counterparts. Therefore, closure duration was one of the cues that distinguished between the speakers of the two dialects of EkeGusii.

The following are the results for the closure duration for /p/ for the children informants.

Table 4.56. Closure duration for /p/ in milliseconds and their SDs for children

speakers	MCM1	MCF2	RCM1	RCF1	Average	SD
pi	104	89	168	154	129	38
pa	91	98	158	147	124	34
po	106	103	161	148	130	29
mean	100	97	162	150	127	34
SD	8	7	5	4	3	4

Closure duration for the bilabial plosive /p/ for children had marginally higher value when it appears in the environment of the vowel /o/ as compared to when it appears with /i/ or /a/. The bigger SD value also implies a larger spread for the values above and below the mean for /pi/ as compared to /pa/ and /po/.

Just like the other two groups of adult males and adult females, the dialect divide was tested for significance. The children speakers of the Rogoro dialect recorded higher scores than their Maate dialect counterparts. Their difference was significant with p=.003, which is interpreted as a pattern that is consistent in the language. This confirms the results for males and females which also did indicate that Rogoro dialect speakers had longer closure duration for bilabial stop /p/.

In general, there was no significant difference between values posted by children and females and between children and males. Hence, closure duration could not be used as a cue for age distinction.

4.2.1.2 Closure duration for /t/

Stop gap or stop closure duration begins roughly as intensity of preceding vowel before stop consonant drops since coming together of articulators is not instant but gradual. That duration of silence ends in a burst typically. Then after the short burst duration, there follows onset of the next vowel. The constriction interval provided a cue for the place of articulation for EkeGusii stops and also an identifier of dialect of a speaker.

The same method used above for measuring closure duration for /p/ was used for measuring /t/. The following table gives the results for the voiceless alveolar stop /t/ for the female informants.

Table 4.57: closure duration average for /t/ for female informants

speaker	ti	ta	to	Mean	SD
MF1	108	104	96	103	6
MF2	123	101	100	108	13
RF3	144	147	145	145	2
RF4	109	122	77	103	23
Mean	121	119	105	115	9
SD	17	21	29	21	6

For the female informants, stop gap interval showed average /t/ closure duration of 115 milliseconds with a small standard deviation of 9. Average range for the closure duration of /t/ was 12 milliseconds for this group of informants. The low standard deviation values indicate closure results for the individual informants. Nonetheless, there were outliers like RF3 with highest values and MF1 and MF4 with the lowest scores.

There were two categories of adult female informants according to the two dialects in EkeGusii. Tab. 4.58 and 4.59 give results for adult females representing the two dialects.

Table 4.58: closure duration average for /t/ for Rogoro dialect female informants

speakers	ti	ta	to	Mean	SD
MF1	108	104	96	103	6
MF2	123	101	100	108	13
Mean	116	103	98	105	9
SD	11	2	3	4	5

The average closure duration for /t/ for the adult females speaking the Rogoro dialect was 105 milliseconds. The average range was 5 milliseconds and a standard deviation of 9. The values indicate a small spread from the mean which means that the scores were fairly homogeneous.

This was compared to the results for the adult females who speak EkeMaate dialect as follows.

Table 4.59: Closure duration average for /t/ for Maate dialect female informants

speakers	ti	ta	to	Mean	SD
RF3	144	147	145	145	2
RF4	109	122	77	103	23
Mean	127	135	111	124	12
SD	25	18	48	30	16

The mean closure duration for female speakers of EkeMaate dialect was 124 milliseconds. The average range was 42 milliseconds and a standard deviation of 12.

A T-test carried out to confirm whether the differences were significant yielded a p=0.1. This confirms the low standard deviations as indicators for a homogeneous group with negligible spread from the average score. The differences were not as a result of patterns in the language statistically but rather chance.

Tab 4.60 shows the results for male subjects for closure duration of /t/.

Table 4.60: closure duration average for /t/ for adult male informants

speakers	ti	ta	to	Mean	SD
RM1	120	134	131	128	7
RM2	124	115	102	114	11
MM3	74	60	72	69	8
MM4	83	66	63	71	11
Mean	100	94	92	95	4
SD	25	36	31	30	5

Just like for the results of /p/ above, the males had slightly shorter closure duration for /t/ as compared to the females. The difference between the values of adult females and adult males had a p-value of 0.004. /t/ had average occlusion duration of 95 milliseconds with a range of 8 milliseconds. This was translated to mean that it is a pattern in the language to have females with higher values as compared to males.

The average range was 53 milliseconds. The stop consonant /t/ had longest closure duration when it came in the environment of the vowel sound /i/ at 100 milliseconds, 92 milliseconds in the environment of /o/ and the least was 94 milliseconds in the environment of /a/.

In terms of dialect differences, the following results were presented by EkeRogoro and EkeMaate dialect speakers on Tab 4.61 and 4.62 respectively.

Table 4.61: closure duration average for /t/ for Rogoro adult male informants

speakers	ti	ta	to	Mean	SD
RM1	120	134	131	128	7
RM2	124	115	102	114	11
Mean	122	125	117	121	4
SD	3	13	21	10	9

Average closure duration for the males who speak the Rogoro dialect is 121 milliseconds with a range of 14 and a standard deviation of 4.

These males had the longest closure duration in the environment of /a/ at 125 milliseconds, 122 milliseconds in the environment of /i/ and 117 milliseconds in the environment of /o/.

The males who speak EkeMaate dialect of EkeGusii had the following results for the closure duration of /t/.

Table 4.62: closure duration average for /t/ for Maate adult male informants

speakers	ti	ta	to	Mean	SD
MM3	74	60	72	69	8
MM4	83	66	63	71	11
Mean	79	63	68	70	8
SD	6	4	6	1	1

The range for these males was 16 milliseconds and average /t/ closure gap was 70 milliseconds. The longest duration was in the environment of /i/ at 79 milliseconds and the shortest duration was in the environment of /a/ at 63 milliseconds.

Significance test resulted in p=0.004 which meant that the differences between the means of the two dialects was as a result of a pattern in the language and not out of chance with a more than 99% confidence rate.

Tab. 4.63 gives a summary for the closure duration for the alveolar stop /t/ for children subjects for this study.

Table 4.63. closure duration for /t/ in milliseconds and their SDs for children

Stop/vowel	MCM1	MCF2	RCM1	RCF1	Average	SD
ti	119	96	106	127	112	14
ta	99	92	101	125	104	14
to	112	87	99	119	104	14
mean	110	92	102	124	107	13
SD	10	4	4	4	4	0

Informant MCM1 had the highest spread of values for the nine tokens with an individual SD of 10. The other children stood at 4 meaning that they had scores very close to their personal means. The average score for the children was minimally spread as indicated by the low SD of 4. For the dialectal variation, the Rogoro speakers had longer closure duration for the alveolar stop /t/ as compared to their Maate counterparts. There was a significant difference between them at p=0.025. This confirms the trend from the other groups and other stop consonants whereby the speakers of Rogoro dialect had longer closure duration.

4.2.1.3 Closure duration for /k/

Stop gap for voiceless velar stop for all the tokens of /k/ was measured, and then their means were calculated for every subject. The following are the results for female informants.

Table 4.64: closure duration average for /k/ for adult female informants

speakers	ki	ka	ko	Mean	SD
MF1	130	130	126	129	2
MF2	96	114	121	110	13
RF3	201	152	205	186	30
RF4	123	104	94	107	15
Mean	138	125	137	133	7
SD	45	21	48	37	15

The results for this group of informants indicate that generally, /k/ has the longest closure duration of all the three stop consonants in EkeGusii for adult females and for all other groups as well. This group showed that the consonant /k/ was longest when it came in the environment of the vowel sound /i/ with an average of 138 milliseconds. This was followed by 137 milliseconds when it came together with vowel /o/. After the vowel sound /a/ it recorded the lowest closure duration of 125 milliseconds.

The average range here was 8 milliseconds. The average closure duration for /k/ for the female subjects was 133 milliseconds and a standard deviation of 7. However, there was no difference between the Maate and Rogoro dialect speakers as T-test results were all with a value of $p>0.05$. These gave an indication that for adult females, closure gap duration was homogeneous.

The following are the results for closure duration for the stop consonant /k/ as recorded for male subjects.

Table 4.65: closure duration average for /k/ for adult male informants

subjects	ki	Ka	ko	Mean	SD
RM1	90	111	115	105	13
RM2	129	119	132	127	7
MM3	74	60	58	64	9
MM4	83	66	63	71	11
Mean	94	89	92	92	3
SD	24	30	37	30	6

For voiceless velar stop /k/, for these male informants, closure duration was longest when it came in the environment of the vowel /i/ at 94 milliseconds; 89 milliseconds in the environment of /a/ and 92 milliseconds in the environment of /o/.

Average closure duration for the stop consonant /k/ is 92 milliseconds. Average range was 5 milliseconds and a standard deviation of only 3. This means that all the mean scores for the various subjects were very close together.

The difference between the values for males and those of females was significant as the p value was 0.001. This difference mathematically means that the difference was significant, that it is a pattern consistent in the language where females have longer stop gap durations.

Another difference was expected between the speakers of EkeMaate and EkeRogoro dialects of EkeGusii. Statistically, the differences were significant for males and not significant for females; Student's test had p=0.004 for male informants and p=0.1 for females.

For adult informants in general, closure duration (others call it constriction interval of silence (Hayward 2013)) for stop consonants starts at the offset of a previous vowel and ends at burst of that stop consonant. The closure duration is longest for EkeGusii velar stop /k/ relatively across all the three groups studied here. The closure duration for /p/ followed in length after /k/ with males and females average at 91 milliseconds where the males had an average of 87 milliseconds and the females had an average stop gap of 94 milliseconds. /t/ had the least stop consonant closure duration of 81 milliseconds for all the groups as the males had an average of 74 milliseconds and 89 milliseconds for the females.

The results for the children are on Tab. 4.66.

Table 4.66. Closure duration for /k/ in milliseconds and their SDs for children

Stop/vowel	MCM1	MCF2	RCM1	RCF1	Average	SD
ki	122	102	132	133	122	15
ka	114	97	126	127	116	14
ko	111	75	113	129	107	23
Mean	116	91	124	130	115	17
SD	6	14	10	3	8	5

The voiceless velar plosive of EkeGusii recorded the longest closure duration as compared to the other two plosives /p/ and /t/. MCF2 was an obvious outlier with low scores and RCF1 with the highest scores. The average range was 15 milliseconds for /ki ka ko/.

The spread of the scores from the mean as seen by the SD values indicate low dispersion from the personal informant and group averages as the SD values are quite low ranging from 3 to 14. The SDs for the average values was slightly higher than the SDs for individual scores.

The results for the children were also tested for dialectal differences between the talkers of EkeMaate and EkeRogoro dialects. The difference between them was significant with p=0.005. Just like the results for the adults, children confirmed that the speakers of EkeRogoro dialect had longer closure duration than speakers of EkeMaate dialect.

4.2.2 Voice onset time

The source of acoustic energy during closure of a stop is voicing (Johnson 2003). During closure, voicing is the only possible sound for; otherwise, the closing is voiceless. This is because articulators are in complete contact and airflow from the voice source to the outside is completely cut. The vocal tract, now closed, completely stifles any turbulence that might cause any sound.

All the above change during release of a stop as it opens several types of sound sources. One of them is stop release, the reason for the other name given to stops; plosives. This happens when increased air pressure behind point of closure is released and the air explodes out of oral cavity at high speed producing some kind of explosion.

The sound wave of a plosive is called a transient. The beginning of a sound wave of a plosive is called a burst, where the wave starts with a spike when articulators are opening and there is a release of a plosive. To measure VOT in a plosive, measurement is done from burst, which is the point of release of plosive, until the sound wave becomes periodic. Praat edit window below shows the part highlighted of stop consonant /k/ as produced by adult male informant, RM2, from burst to start of voicing of following vowel. At the point of periodicity, vocal folds vibrate.

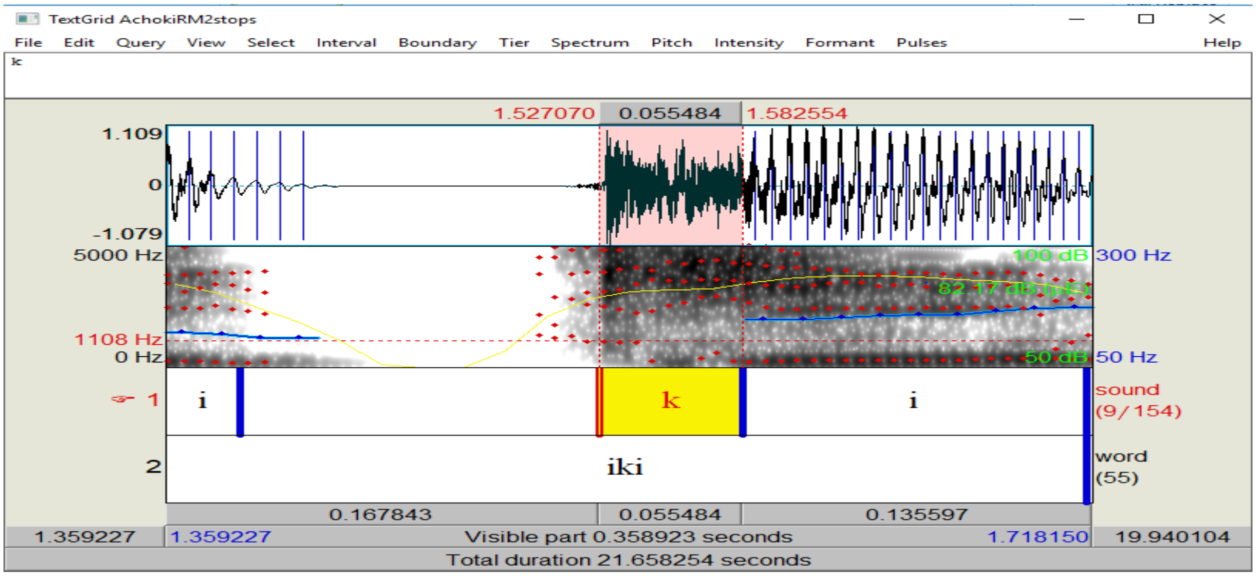


Figure 4.59: waveform and spectrogram of VOT for /k/ for adult male (RM2) informant

The figure above shows that VOT for /k/ for RM2 for this token was 55 milliseconds, considering the first three digits after the decimal point. Thus, all the others were annotated and measured for this research.

The three Ekegusii stop consonants /p, t, k/ are all voiceless. Each of them has a different place of articulation; /p/ is a voiceless bilabial stop; /t/ is a voiceless alveolar stop, and /k/ is a velar stop. With each having a different place of articulation, we expect to see differences in the VOT.

By observing the waveforms and spectrograms on Praat, it was possible to acquire empirical base for defining stop segments in Ekegusii. On the waveform and spectrogram above, a stop like /k/ appears as a thin vertical line of noise energy before a vowel that is indicative of a stop burst. The three stops differ in their waveform and attending F1 and F2 of the following vowel sound according to the place of articulation. The transitory rise of F2 between the stop and the ensuing vowel is evident in the spectrogram.

When analysing a sound wave from the beginning of the burst to the beginning of voicing, that is, when the sound wave starts to be periodic, we get VOT value. This has to be done manually since the computer's approximation through beginning of the F0 contour can be a bit delayed and therefore not reliable. The pitch contour in blue indicates that voicing of ensuing vowel starts much later while the waveform displays otherwise. In the selection above, the VOT is recorded to take 0.055 seconds which is approximately 55 milliseconds. The pulse option on the Edit window can be used to get voice report for the target stops.

4.2.2.1 Voice onset time for /p/

Bilabial stop /p/ is produced with the lips completely obstructing air turbulence for a moment before release which is seen as a burst spectral shape on the waveform. From the burst of the stop consonant to the point where voicing of next vowel starts is called VOT. Again, differences between females and males were noted and analysed for their significance using Student's test.

The space in time between the onset of the burst and the onset of the following vowel is the duration for the stop /p/. Once this part was highlighted, query menu on the view and edit menu provided a way of finding selection length. This time in seconds, was copied and pasted on Excel spread-sheets. This was also changed into milliseconds for easy calculation and presentation. The measurements were done for all voiceless bilabial plosives /p/ at intervocalic position in words. Finally, means for all the instances were derived.

VOT results for female informants were as follows.

Table 4.67: VOT averages for adult females

speakers	pi	pa	po	Mean	SD
MW1	7	9	8	8	1
MW2	8	8	7	8	1
RW3	11	9	7	9	2
RW4	7	8	7	7	1
Mean	8	9	7	8	1
SD	2	1	1	1	1

From the Tab. 4.67, it can be seen that VOT duration ranges from 7 to 11 milliseconds. It should suffice to say that the values were nearly homogeneous

With a Standard deviation of 1, the VOT differences were negligible. The average range recorded for these informants was 2 milliseconds, that is, the longest recorded average duration of 9 milliseconds and the shortest span of 7 milliseconds.

The female informants never indicated any significant variation between the two dialects of EkeGusii. T-test results had p=0.085 which is higher than the accepted minimum of p=0.05. Therefore, VOT cue could not be used to distinguish between the two dialects for female informants in this study.

The results for the male informants were recorded on the Tab. 4.68 below.

Table 4.68: VOT averages for adult males

VOT for men	RM1	RM2	MM3	MM4	Average	SD
pi	8	12	7	10	9	2
pa	8	8	5	8	7	2
po	9	8	6	8	8	1
mean	8	9	6	9	8	1
SD	1	2	1	1	1	4

The average range of the VOT length of /p/ for males was 3 milliseconds. The high vowels seem to make the VOT of stop consonant longer at averagely 8 milliseconds. The front vowel /i/ makes the stop to have an average length of 9 milliseconds, the longest recorded average here; vowel sound /a/ brings the VOT down to 7 milliseconds and /o/ makes it 8 milliseconds long. The only central vowel /a/ realises the shortest span for the stop consonant as it was for the results of females above. The average VOT duration for /p/ was 8 milliseconds with a standard deviation of 2.

Just like adult females seen above, adult males had very close VOT values to the extent that the difference between the females who spoke EkeRogoro dialect and those who spoke Ekemaate dialect was not significant.

The last group was that of the children. The following chart and table shows the results for the children sampled by this study.

Table 4.69: VOT averages for children

Stop VOT	MCM1	MCF2	RCM2	RCF1	Average
Pi	13	14	16	17	13
Pa	7	8	11	12	8
Po	11	10	13	13	10
Mean	10	11	13	14	10
Standard Deviation	3	3	3	3	3

Each of the select EkeGusii vowels affected VOT duration of preceding stop consonant /p/ variously. Average range was only 5 milliseconds. The average duration for /p/ for children speakers was 10 milliseconds.

VOT of /p/ was 13 milliseconds in the enviroment of /i/; it was 10 milliseconds long vowel sound /o/ and after /a/ it was 8 milliseconds long. The average range recorded for children was 5 milliseconds with a standard deviation of 3.

The mean duration for children is shortest then followed by adult females and then adult males. A Student's test conducted on the scores for females against those of males yielded $p=0.18$ which is far much higher than what is statistically accepted $p<0.05$, hence no significant difference between adult males and adult females. The values confirm that the minor differences were just by chance and not a pattern in the population for adults. Significance test for differences between scores of children and males was $p=0.02$ which was significant; between children and adult females yielded 0.03 which was also significant. From the foregoing, we can conclude that the VOT duration for the bilabial plosive /p/ could be differentiated by age with children having significantly longer VOT duration as compared to adult speakers.

4.2.2.2 Voice onset time for /t/

Let me turn to the second stop consonant, voiceless alveolar stop /t/. It is the articulation of this sound that intrinsically identifies dialects of Ekegusii speaker. The following are results for sound /t/ at intervocalic position in the environment of /i/ for *ti**ti*** 'carry (baby) on the back', *a**ta**ta* 'break (things) all-over', and *o**t**oto* 'vegetable name'. The majority of Ekegusii speakers believe that Maate dialect speakers pronounce /t/ sound with some voicing making it /d/ rather than /t/. This claim was tested here from waveform and spectrogram traces below that compare /t/ for a male speaker of Maate dialect (MM4) and another of Rogoro dialect (RM2).

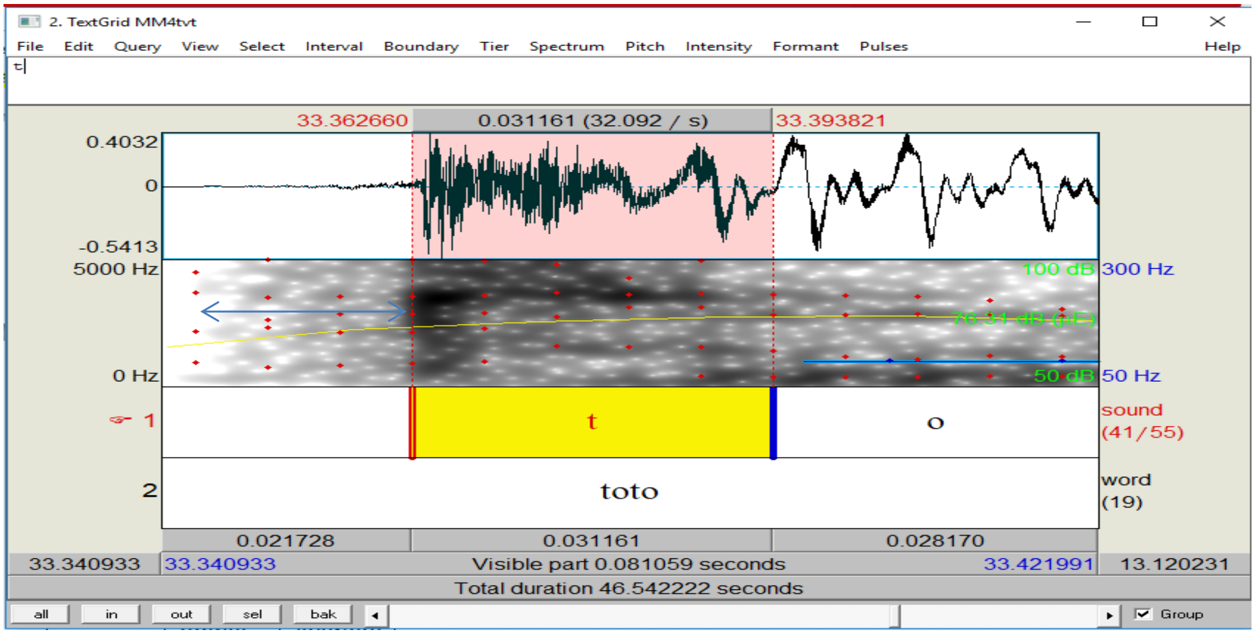


Figure 4.60: waveform and spectrogram of /t/ by MM4

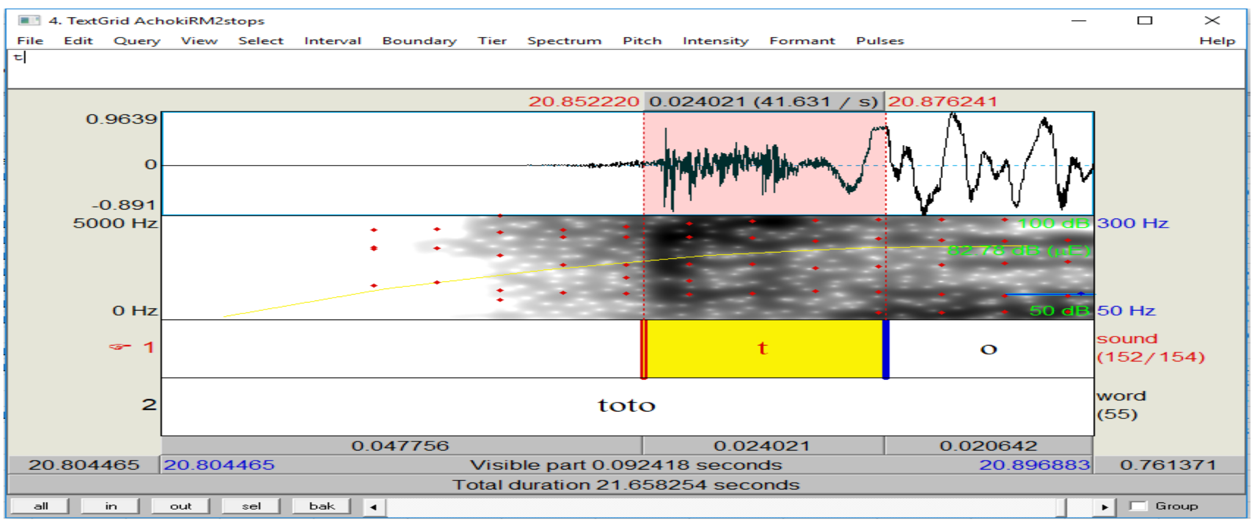


Figure 4.61: Waveform and spectrogram of /t/ by RM2

Clearly, the waveforms and spectrograms above do not indicate any major difference in their trajectories from stop burst to onset of voicing of following vowel. If it were indeed true that /t/ produced by speakers of Maate dialect of Ekegusii was voiced, then the spectrograms should have had lead VOT, that is, onset of voicing before stop burst. Again, the stop should have a very brief burst of less than 5 milliseconds then onset of following vowel voicing. None of these is observed on the waveform or spectrogram of all the speakers of Maate dialect. This refutes the claim that the Maate dialect speakers have a voiced /t/ allophone. Since it sounds different, then there must be another explanation. Maybe, the tongue tip is drawn further back from the alveolar ridge or the sound is retroflexed; but whatever the case, more analysis needs to be done.

Tab. 4.70 presents the VOT group averages for adult male informants.

Table 4.70: VOT averages for /t/ for males

Stop/VOT	RM1	RM2	MM3	MM4	Average	SD
ti	22	36	18	16	23	9
ta	19	18	10	13	15	4
to	14	15	11	12	13	2
mean	18	23	13	14	17	5
SD	4	11	5	2	5	4

The average VOT duration for adult males was 17 milliseconds. When coming in intervocalic position of /i/ it recorded 23 milliseconds and /o/ 13 milliseconds, and the environment of low central vowel /a/ had a mean of 15 milliseconds.

The four adult male informants could also be grouped into two: speakers of Maate and Rogoro dialects of Ekegusii. A Student's test carried out on the scores between these two groups yielded a p value of 0.02. This value is statistically significant meaning that Maate dialect speakers had a consistently and significantly shorter VOT duration than their Rogoro counterparts. This result is the closest to suggesting voiced nature of Maate dialect /t/, shorter VOT duration. The very small value of standard deviation ranging from 1-2 indicated that the values were not widely dispersed from the mean.

The second group of informants was that of females. The values below indicate how adult female speakers presented VOT.

Table 4.71: VOT duration for /t/ for adult females

Subject/VOT	ti	ta	to	Mean	SD
MW1	26	13	21	20	7
MW2	18	13	16	16	3
RW3	19	10	10	13	5
RW4	24	12	14	17	6
Mean	22	12	15	16	5
SD	4	1	5	3	2

Females had an average range of 16 milliseconds with the highest recorded VOT duration for /t/ coming in the environment of /i/ at 22 milliseconds on average. When used with /a/ it averaged at 12 milliseconds, with /o/ it was at 15 milliseconds. Mean VOT for /t/ for these speakers was 16 milliseconds with a standard deviation of 5.

Significance tests on the differences between the females of the two aforementioned dialects of Ekegusii yielded a $p>0.05$. This meant that there was less than 95% chance that the score differences were a pattern in the language. This was not consistent with the results of males that indicated that speakers of Maate dialect and Rogoro dialects had significant difference between their VOT duration.

The following are the mean VOT values for the stop consonant /t/ in the environment of select Ekegusii vowels for children informants.

Table 4.72: VOT duration for /t/ for children

Stop/vowels	MCM1 VOT	MCF2 VOT	RCM2 VOT	RCF1 VOT	Average VOT
ti	21	27	25	29	24
ta	15	15	16	22	15
to	13	13	20	26	13
mean	16	18	20	26	17
Standard Deviation	4	7	5	4	6

The children as a group had an average VOT duration of 17 milliseconds with a low SD of 6. Average VOT range was 10 milliseconds. Just like adult females above, children values were not significantly different from either the males or females. There was however, a distinction between the dialects with speakers of Maate having shorter VOT duration as compared to children speakers of Rogoro dialect.

4.2.1.3 VOT for /k/

The last stop consonant is the voiceless velar stop /k/. It is found both at word initial and intervocalic position in Ekegusii. The VOT of the sound was analysed and measured as it occurred at the intervocalic position with /i/, /a/ and /o/ just like the other stop consonants analysed earlier. The following are the results for female informants.

Table 4.73. /k/ VOT averages for females

Subject/VOT	ki	ka	ko	Mean	SD
MW1	45	33	33	37	7
MW2	30	23	20	24	5
RW3	35	22	23	27	7
RW4	39	21	28	29	9
Mean	37	25	26	29	7
SD	6	6	6	6	0

The average VOT for /k/ for females was 29 milliseconds with an average range 11 milliseconds and a standard deviation of 6. /k/ had longer VOT duration when compared with /t/ and /p/ for females. The same pattern is replicated for the adult males and children.

The differences between the females who speak Rogoro and Maate dialects were also investigated and the results showed no significant difference between the two dialects as $p>0.05$.

Tab 4.74 gives VOT results for males for stop consonant /k/.

Table 4.74. /k/ VOT averages for males

Subject/VOT	ki	ka	ko	Mean	SD
RM1	36	18	20	25	10
RM2	53	36	45	45	9
MM3	36	20	26	27	8
MM4	27	22	28	26	3
Mean	38	24	30	31	7
SD	11	8	11	9	2

The males had longer VOT than females as seen above. The average VOT for the males was 31 milliseconds as compared to the females at 29 milliseconds. The average range was 14 milliseconds with a standard deviation of 7.

The difference between Maate and Rogoro dialect speakers was not significant at $p>0.05$. This means that any variation between the values was a random and cannot be attributable to a pattern in the language.

Table 4.75. /k/ VOT averages for children

Stop/VOT	MCM1	MCF2	RCM2	RCF1	Average
ki	38	40	44	42	39
ka	28	29	31	33	28
ko	24	20	29	32	22
Mean	30	30	35	36	30
Standard Deviation	7	10	8	6	8

Average VOT for /k/ for children was 30 milliseconds. This was almost equal to that of adult females and adult males respectively. The average range recorded for the children was 17 with an SD of 8.

Significance test between the two dialects of Ekegusii for children yielded a $p>0.05$ meaning that the differences were not significant, just random and not patterns found in the language.

Table 4.76: Average VOT for /k/ for males, females and children

Group/VOT	Children	Females	Males
ki	39	37	38
ka	28	25	24
ko	22	26	38
Mean	30	29	31
SD	8	8	12

Tab. 4.76 shows that adult males had, just slightly, the longest average VOT duration for the stop consonant /k/ at 31 milliseconds, followed by children at 30 milliseconds and lastly the adult females at 29 milliseconds. The average range for the three groups was 2 milliseconds and an SD of 4. For all the three Ekegusii stop consonants, male informants had longer stop consonant durations as compared to the values got from female informant. That notwithstanding, the results were not significantly different for the three groups. The conclusion that VOT duration could not be used to discriminate between the two dialects, age and sex of the informants.

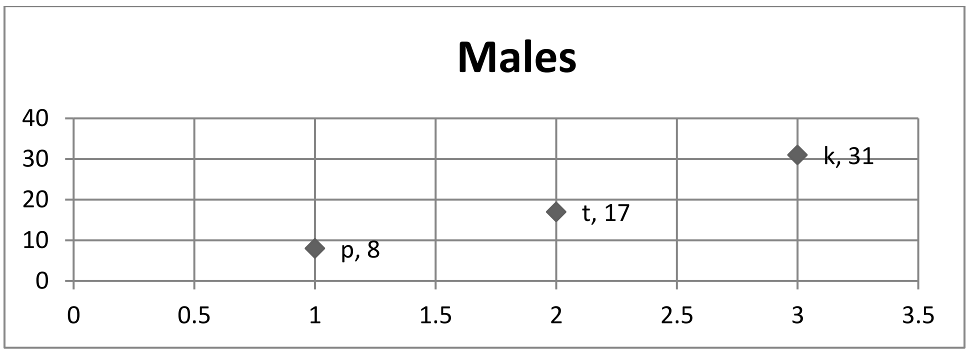
4.2.1.4 VOT summary

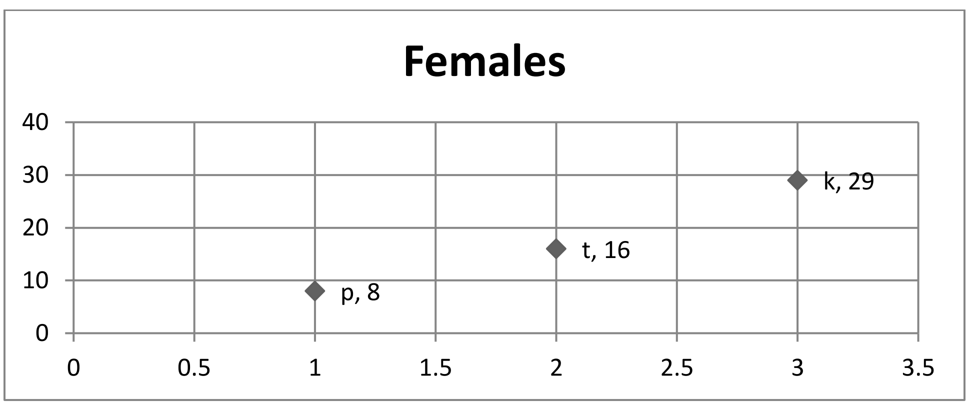
Tab. 4.77 gives a summary of the total duration for the three stop consonants in Ekegusii. Each is measured in an intervocalic environment.

Table 4.77 *Average VOT duration for males, females and children*

stop consonants	Males	Females	Children
p	8	8	14
t	17	16	17
k	31	29	30

Tab. 4.77 can be represented on a scatterplot so as to show the differences between the average values of each of the stop consonants in Ekegusii.





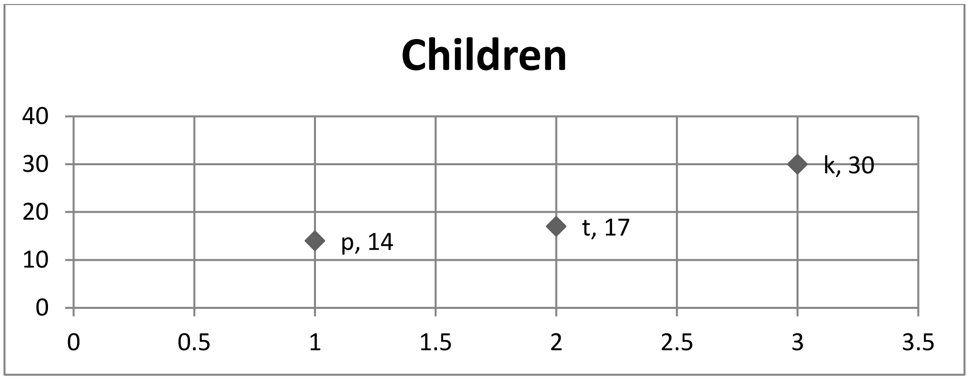


Figure 4.62a, b, c: Combined Mean VOT duration for males, females and children

Fig. 4.62 showed that /p/ had the lowest total duration mean of 12 milliseconds followed by /t/ with a mean of 20 milliseconds and /k/ had the longest mean at 37 milliseconds. Place of articulation was a discriminatory factor from the values above. The labial plosive /p/ had the lowest VOT duration followed by the alveolar plosive /t/ and then the velar plosive /k/. The differences were significant from between p=.002 to p=.001.

4.2.3 Fundamental frequency after stop consonants

Fundamental frequency (F0) of the vowel following stop consonants is one of the cues that distinguish between the voiced and voiceless stop. F0 values for vowels following voiceless stops are higher than those for vowels following voiced stops. Ekegusii does not have voiced stops yet the speakers of the Maate dialect have for long been believed to use /d/ instead of /t/ as it is in the Rogoro dialect. This research tested the validity of this impressionistic view with the evidence from F0 values after the Stop.

4.2.3.1 Results for /p/

Tab. 4.79 gives average vowel onset for F0 after stop consonant /p/ in Ekegusii for males in three vowel environments as: /pipipi/, /papapa/ and /popopo/. The second syllable was under focus since it was located intervocalically.

Table 4.79: F0 at Vowel Onset After Stop Consonant /p/ for male informants

Stop/vowel	RM1	RM2	MM3	MM4	AVERAGE
pi	143	143	98	159	136
pa	116	140	102	116	119
po	120	121	151	130	130
mean	126	135	117	135	128
SD	15	12	30	22	19

The average F0 frequency for /p/ for all the male informants was 128 Hz with an SD of 19. On the higher side, MM4 was an outlier with very high frequency for all instances measured while MM3 had low F0 frequency in nearly all instances. The values are normalized by the group average scores. Tab. 4.79 can be displayed on a bar graph to make it more appealing and for easier comparison in Fig. 4.63.

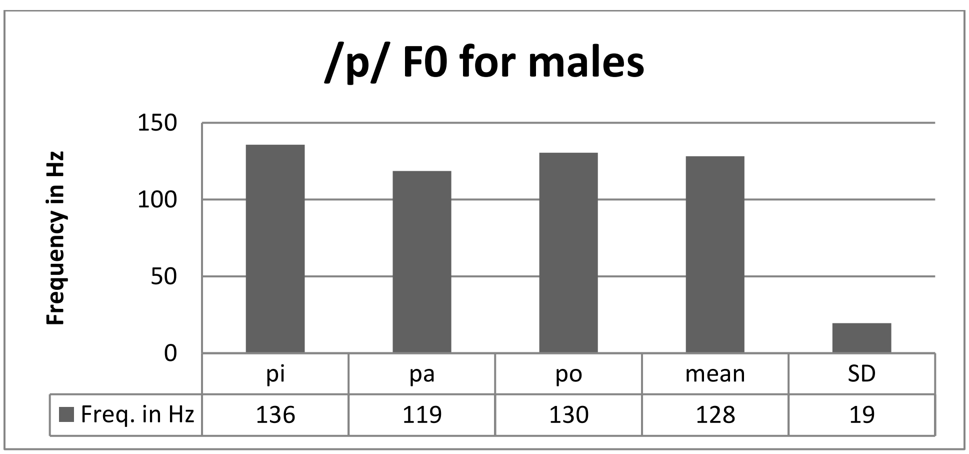


Figure 4.63: F0 at vowel onset after stop consonant /p/ for males

Male respondents record high F0 values following the stop consonant. The highest after /p/ is the F0 for /i/ at 136 Hz and the lowest is 119 Hz with the vowel /a/. The range here was only 17 Hz with an SD of 19. For these male speakers, the high values for F0 confirm that they are truly voiceless. The average range for the voiceless stop consonants is between 100 Hz and 250 Hz.

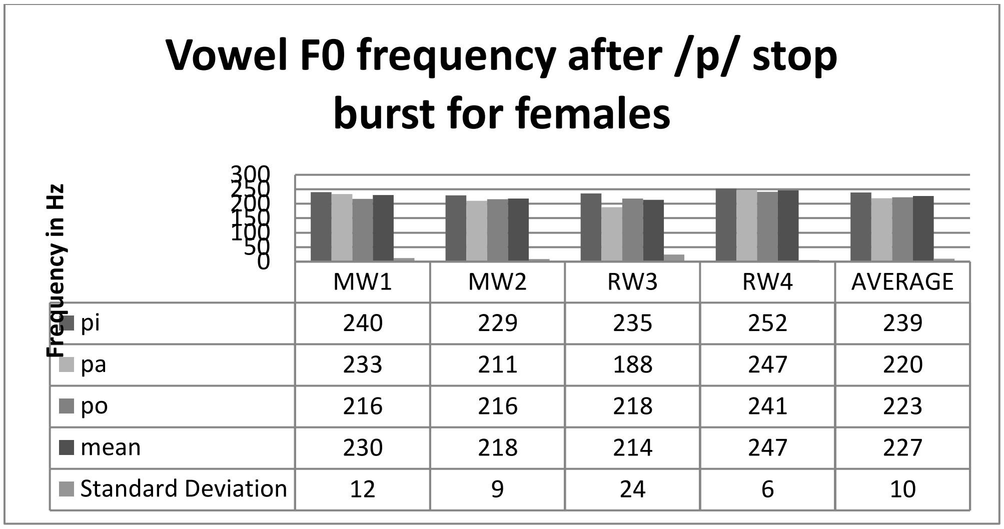
A Student' test carried on the differences between the two dialects of Ekegusii yielded a value of $p>.05$ which statistically is above the minimum required. This meant that the differences were just random and not as patterns in the language for the males.

Values for males were compared to the values for adult females as seen on Tab. 4.78.

Table 4.78: F0 at Vowel Onset after Stop Consonant /p/ for females

Stop/vowel	MW1	MW2	RW3	RW4	AVERAGE
Pi	240	229	235	252	239
Pa	233	211	188	247	220
Po	216	216	218	241	223
Mean	230	218	214	247	227
SD	12	9	24	6	10

Females recorded very low standard deviations except for RW3 who had an SD above 20. Average F0 for vowel after the stop consonant /p/ for females in Ekegusii was 227 Hz and a SD of 10. Fig. 4.64 is a bar graph showing the female values as got from Tab. 4.78.



	MW1	MW2	RW3	RW4	AVERAGE
pi	240	229	235	252	239
pa	233	211	188	247	220
po	216	216	218	241	223
mean	230	218	214	247	227
Standard Deviation	12	9	24	6	10

Figure 4.64: F0 at vowel onset after stop consonant /p/ for females

Just like the males, the females had a small range of 19 Hz and also a small SD of 10. This means that the results of females were clustered close together with no obvious outlier. Again, a Student's test of significance revealed a value higher .05. Consequently, the female speakers from each of the two dialects had only random, individual differences and not recognizable patterned differences in the language.

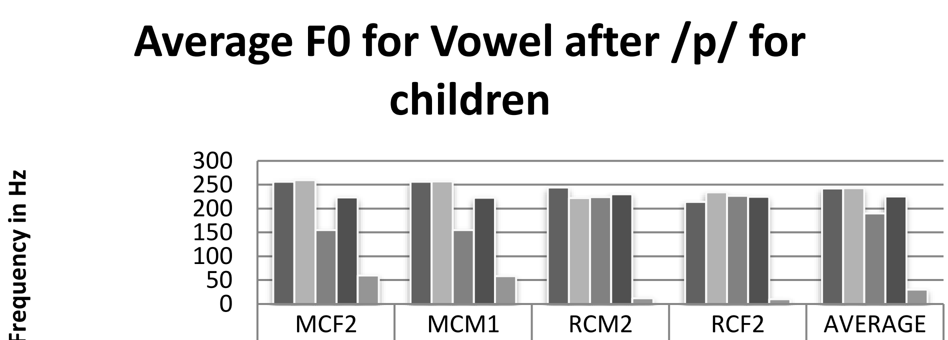
In general, the F0 for the vowel following the stop consonant /p/ in Ekegusii for the females was very high (average of 227 Hz) indicating that the stop consonant was truly voiceless. The female had higher F0 by an average of 99 Hz. This was normal as it is expected for the females to have a higher fundamental frequency than males. The difference was statistically significant with a p-value of .0001 translated to mean that more than 99% likelihood that the results are not random chances but a pattern in the language.

Tab 4.79 gives the results for children informants for this study.

Table 4.79: F0 at Vowel Onset after Stop Consonant /p/ for Children

Children	MCF2	MCM1	RCM2	RCF2	AVERAGE
Pi	256	256	244	214	243
Pa	260	257	222	234	243
Po	155	155	224	227	190
Mean	223	223	230	225	225
SD	60	59	12	10	30

The results for children were a bit scattered as compared to the two other groups. We still note that the average F0 for the vowel after the stop consonant /p/ was 225 Hz, lower than that of won by 2 Hz. The average range recorded for the three instances under investigation was 53 Hz an SD of 30. Fig. 4.65 gives a visual display of the results as displayed by the children for the stop consonant /p/.



	MCF2	MCM1	RCM2	RCF2	AVERAGE
pi	256	256	244	214	243
pa	260	257	222	234	243
po	155	155	224	227	190
mean	223	223	230	225	225
Standard Deviation	60	59	12	10	30

Figure 4.65 F0 at vowel onset after stop consonant /p/ for children

Females and children had nearly the same values for F0 after the stop consonant /p/ in Ekegusii. Significance test between them yielded a figure higher than the significant threshold of .05. The difference between males and children were significant with p=.0001.

4.2.3.2 Results for /t/

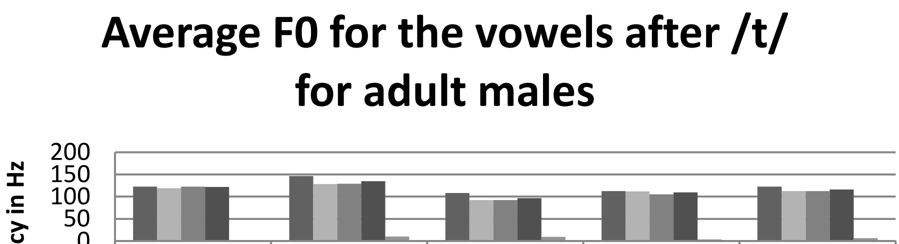
Ekegusii stop consonant /t/ has been looked at with interest for being the identifying factor of Rogoro and Maate dialects. Impressionistic comments show that Maate dialect speakers use /d/ wherever /t/ occurs. All the instances of /t/ were therefore tested for cues that identify the stop sound as either /t/ or /d/ to see the merit of this claim acoustically.

Tab. 4.80 shows the results for adult male informants.

Table 4.80: F0 at Vowel Onset after Stop Consonant /t/ for Males

results for men	RM1	RM2	MM3	MM4	AVERAGE
ti	123	146	108	112	122
ta	119	129	92	112	113
to	123	129	92	105	112
mean	122	135	97	110	116
SD	2	10	9	4	6

At an average of 116 Hz, F0 for vowel onset for the males after alveolar stop /t/ is still high meaning that that the sound is indeed voiceless, falling within the range of 100 -250 Hz for voiceless stops according to Ladefoged & Disner (2012). Fig. 4.66 is a graphical display of how each informant presented mean and standard deviation.



	RM1	RM2	MM3	MM4	AVERAGE
ti	123	146	108	112	122
ta	119	129	92	112	113
to	123	129	92	105	112
mean	122	135	97	110	116
SD	2	10	9	4	6

Figure 4.66: F0 at vowel onset after stop consonant /t/ for males

Adult males had very low SDs an indication that individual scores were not much dispersed from the average score of 116 Hz. Average SD was 6 and average range was 10 Hz. There was an indication though that the first and second male had higher frequencies than the third and fourth male. This was also the divide between the Maate and Rogoro dialects. Tab. 4.81 gives the results for the males who speak the Rogoro dialect of Ekegusii.

Table 4.81: *F0 at Vowel Onset after Stop Consonant /t/ for male speakers of Rogoro dialect*

results for men	RM1	RM2	average
ti	123	146	135
ta	119	129	124
to	123	129	126
mean	122	135	128
SD	2	10	6

The adult males who speak Rogoro dialect have an average F0 of 128 Hz which is 12 Hz higher than the average F0 for all males. This means that the males who speak the Rogoro dialect had their /t/ to be more voiceless than the males who speak the Maate dialect as seen on Tab. 4.81. The graphic representation of the Rogoro dialect male's scores is captured in Fig. 4.67.

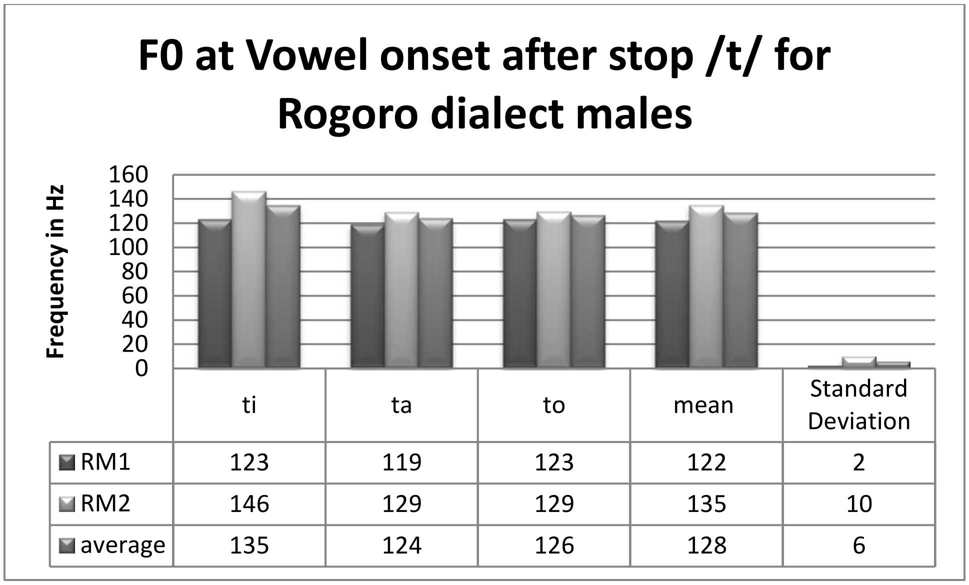


Figure 4.67: F0 at vowel onset after stop consonant /t/ for Rogoro dialect males

The second male here had consistently higher scores than the first male. The average for these males who speak the Rogoro dialect was 128 Hz, an average range of 13 and an SD of 6. We can compare these figures with the results for the males who speak the Maate dialect of EkeGusii in Tab. 4.80 gives the results for the males who speak the Maate dialect.

Table 4.82: *F0 at Vowel Onset after Stop Consonant /t/ for male speakers of Maate dialect*

results for men	MM3	MM4	AVERAGE
ti	108	112	110
ta	92	112	102
to	92	105	99
mean	97	110	103
SD	9	4	6

The average range for the male speakers of the Maate dialect was 11 Hz with an SD of 6. This mean that the two speakers had their individual scores not far removed from their common group mean. Despite that, MM3 had low scores consistently as compared to MM4. Fig. 4.68 gives a visual display of the Maate dialect scores and the group mean.

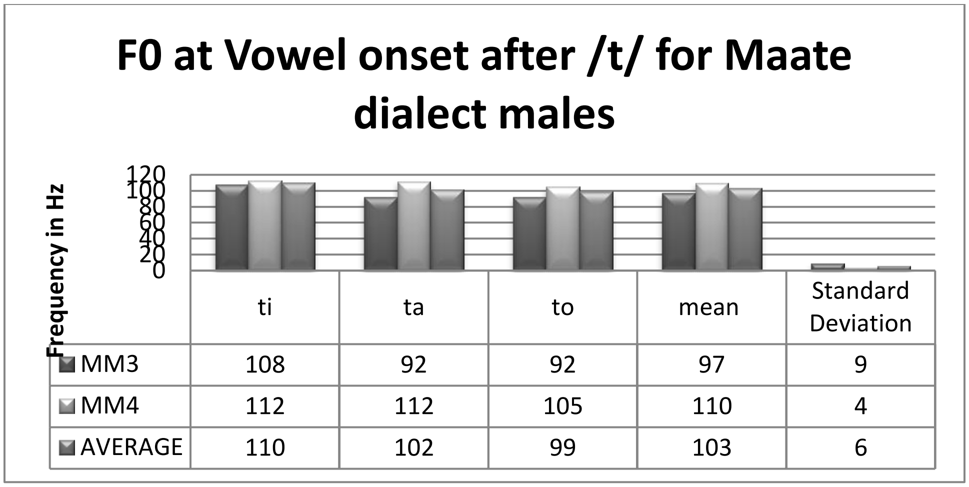


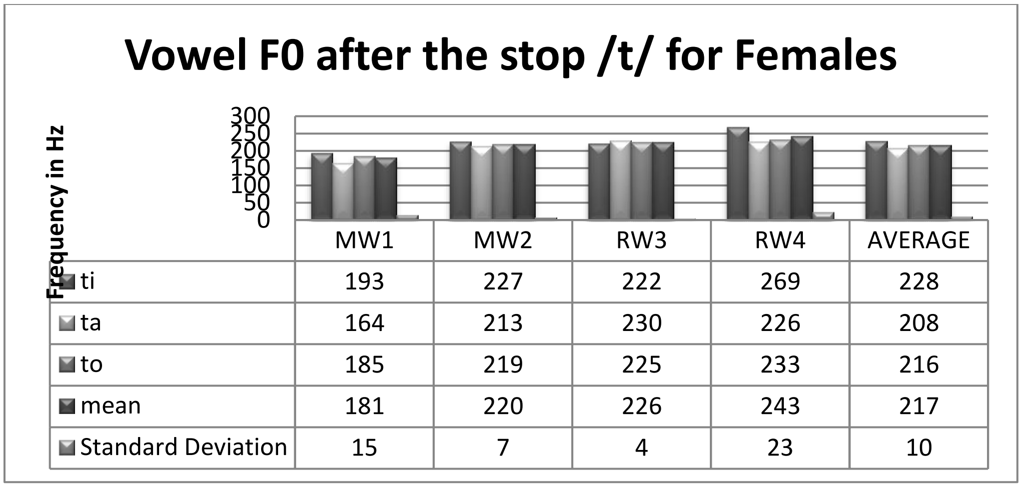
Figure 4.68: F0 at vowel onset after stop consonant /t/ for males who speak the Maate dialect

Significance test carried out to find whether the differences between the scores for the males who speak the Maate dialect and those who speak the Rogoro dialect were significant yielded p-value of 0.00016. This was far below the threshold of p<.05 which means that the differences between the two dialects were statistically significant and not out of just random chance in the population. The adult females presented results as captured on Tab. 4.83.

Table 4.83: F0 at Vowel Onset after Stop Consonant /t/ for female speakers

Stop/Vowel	MF1	MF2	RF3	RF4	AVERAGE
ti	193	227	222	269	228
ta	164	213	230	226	208
to	185	219	225	233	216
mean	181	220	226	243	217
SD	15	7	4	23	10

Adult females had an average F0 for the vowels after the stop consonant /t/ of 217 Hz, an average range of 20 Hz and an SD of 10. The range for the females was higher than that of the males and generally, females had almost twice the F0 for the males. MW1 and RW4 had scores on the extreme low and extreme high respectively as seen on Tab. 4.83.



	MW1	MW2	RW3	RW4	AVERAGE
ti	193	227	222	269	228
ta	164	213	230	226	208
to	185	219	225	233	216
mean	181	220	226	243	217
Standard Deviation	15	7	4	23	10

Figure 4.69: F0 at vowel onset after stop consonant /t/ for females.

There is evidence from a general view of Fig. 4.81 that the MW1 and MW2 have lower scores than RW3 and RW4. This can be made manifest when separated into groups for Maate and Rogoro dialect.

Table 4.84: F0 at Vowel Onset after Stop Consonant /t/ for female speakers of Rogoro dialect

Rogoro females	RW3	RW4	Average
ti	222	269	245
ta	230	226	228
to	225	233	229
mean	226	243	234
SD	4	23	14

The average F0 of vowel after the stop consonant /t/ for the females who speak the Rogoro dialect was 234 Hz. this was 17 Hz higher than the mean for the females as a whole with 234 Hz. the average range was 16 Hz and an SD of 14. These results are better displayed on a bar graph Fig. 4.70.

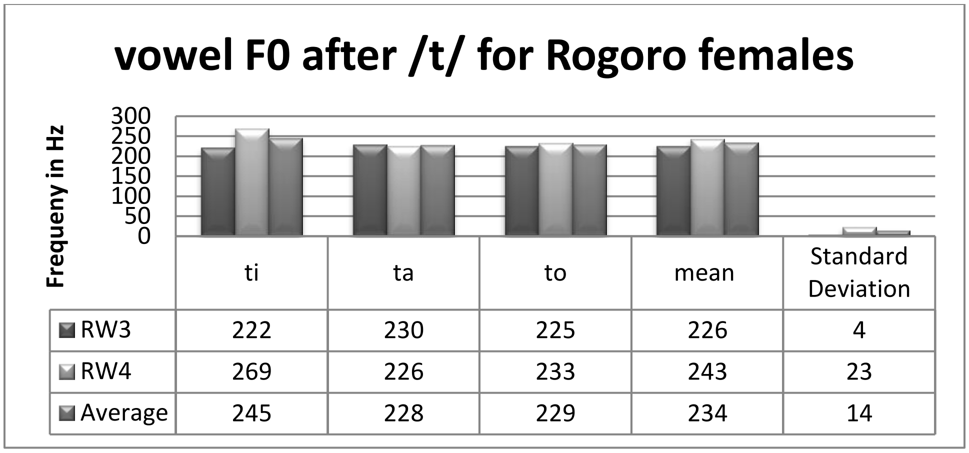


Figure 4.70. F0 at vowel onset after stop consonant /t/ for females who speak the Rogoro dialect

Just like the males, there was also an indication that the females who speak the Maate dialect had lower scores than their Rogoro dialect counterparts. Tab. 4.85 has the results for the females who speak the Maate dialect.

Table 4.85: F0 at Vowel Onset after Stop Consonant /t/ for female speakers of Maate dialect

Maate females	MW1	MW2	Average
ti	193	227	210
ta	164	213	189
to	185	219	202
mean	181	220	200
SD	15	7	11

Average F0 for the vowels after the stop consonant /t/ for female speakers of the Maate dialect was 200 Hz, lower than that of the females informants that speak the Rogoro dialect by 34 Hz. Females who speak Maate dialect had an average range of only 11 Hz and an average SD of 11. This tarries with the results of VOT that suggest that the stop consonant /t/ for the Maate dialect speakers tends to have some voicing. Fig. 4.71 is the graphical display of the Maate dialect females F0 values.

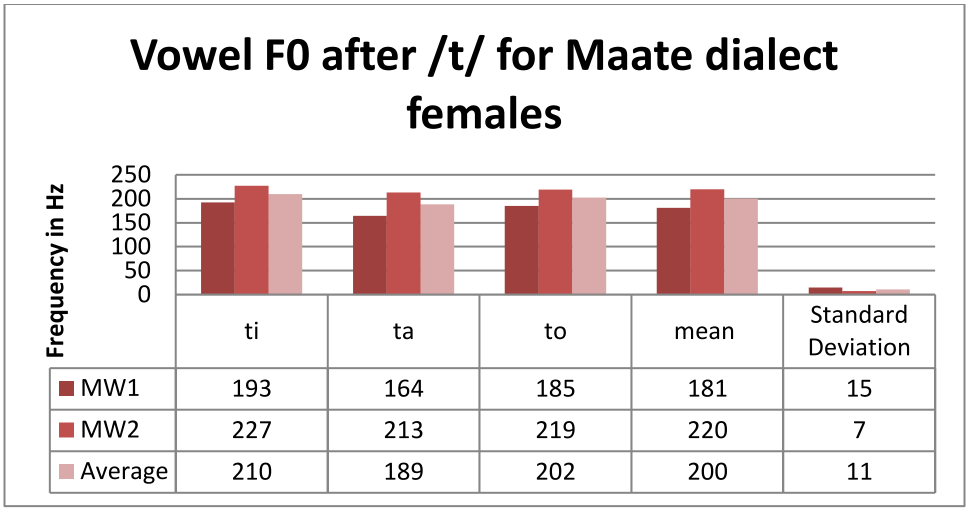


Figure 4.71. F0 at Vowel Onset after Stop Consonant /t/ for female speakers of the Maate dialect

The Students test on the differences between the Rogoro and Maate dialects for the females had a p=.001. The results therefore were highly significant as a generalizable trend in the language that the Maate dialect speakers had a lower F0 for vowels after stop consonant /t/.

The results for children are summarised on Tab. 4.86.

Table 4.86. F0 at Vowel Onset after Stop Consonant /t/ for children informants

children	MCF2	MCM1	RCM2	RCF2	AVERAGE
ti	238	286	195	233	238
ta	184	185	198	216	196
to	247	247	194	221	227
mean	223	239	196	223	220
SD	34	51	2	9	22

The children had an average vowel F0 after the stop consonant /t/ of 220 Hz. The average range recorded for the females was 42 Hz and an SD of 22. The results for the children are better visually displayed on Fig. 4.72.

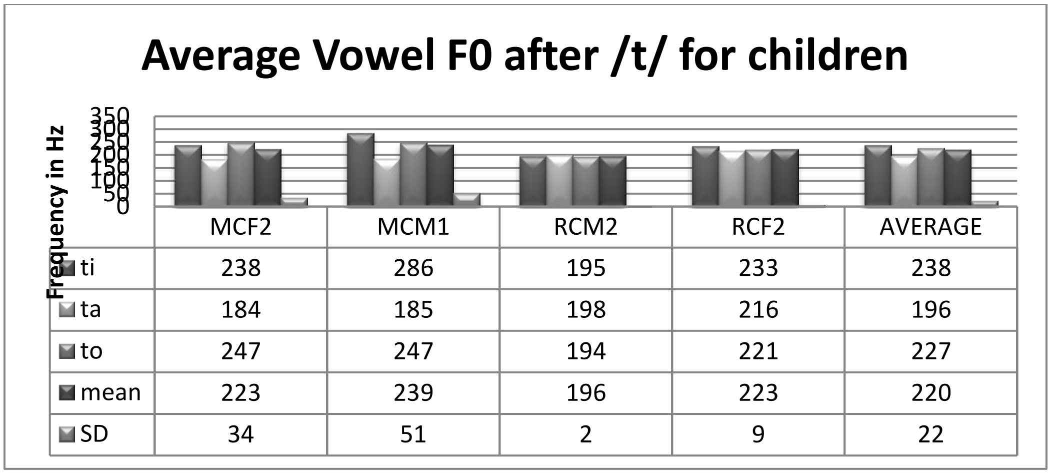


Figure 4.72: children F0 for stop consonant /t/

The children and the females had similar values and the T-tests show that these two groups (females and children) had no significant differences between their values. Children's F0 values were significantly different from those of males where the p-value was 0.001. Again, there was no significant difference between the children who speak the Maate dialect and those who speak the Rogoro dialect.

4.2.3.3 Results for /k/

This section presents results for the F0 measures for the vowels after the voiceless velar plosive in EkeGusii. Tab. 4.87 gives the results for the males who were sampled for this study.

Table 4.87: *F0 at Vowel Onset after Stop Consonant /k/ for adult male informants*

Males /k/	RM1	RM2	MM3	MM4	AVERAGE
ki	121	142	135	129	132
ka	111	108	137	118	118
ko	112	113	142	117	121
Mean	115	121	138	122	124
SD	6	18	4	7	9

For the males as a group, the average measure for F0 of vowels after the stop consonant /k/ was 124 Hz. The mean range recorded was 14 Hz and an SD of 9. The scores were not dispersed much from the average as they were nearly homogeneous.

The values for males were divided further into two for the Maate and Rogoro dialects of Ekegusii. Tab 4.88 shows the results for the males who speak the Rogoro dialect.

Table 4.88: F0 at Vowel Onset after Stop Consonant /k/ for male informants who speak the Rogoro dialect of Ekegusii

Rogoro dialect males	RM1	RM2	average
ki	121	142	132
ka	111	108	109
ko	112	113	113
Mean	115	121	118
SD	6	18	12

The vowel /i/ had the highest average F0 frequency when coming after /k/ at 132 Hz and the vowel /a/ had the lowest F0 frequency. This gave an indication that vowel height was a pointer to the F0 value, the higher the tongue positions the higher the F0 frequency. Tab. 4.35 also indicates that SD was 12, a low value meaning that the average scores for the males who speak the Rogoro dialect were homogeneous. These values were compared to those of the males who speak the Maate dialect as in Tab. 4.89.

Table 4.89: F0 at Vowel Onset after Stop Consonant /k/ for male informants who speak the Maate dialect of Ekegusii

Maate dialect F0 males	MM3	MM4	AVERAGE
ki	135	129	132
ka	137	118	128
ko	142	117	130
Mean	138	122	130
SD	4	7	2

Tab. 4.89 shows results that are more homogeneous than those for the male speakers of Rogoro dialect because of a very small SD value of 2. The average F0 for these males was 130 Hz and a mean range of 4 Hz.

The results for the two groups of males were compared and tested for significance. The speakers of Maate dialect had an average F0 of 130 Hz and those of the Rogoro dialect had an average of 118 Hz. The difference between the two on a Student's test yielded p=0.04. This means that there was a more than 96% likelihood that the differences between the speakers of the two dialects were a pattern repeatable in the language and not just by chance.

The F0 measurements for the vowel after the stop consonant /k/ for the females are presented on Tab.4.90.

Table 4.90: F0 at Vowel Onset after Stop Consonant /k/ for female informants

Results for males	MW1	MW2	RW3	RW4	AVERAGE
ki	210	223	239	257	232
ka	200	206	218	215	210
ko	203	192	233	215	211
Mean	204	207	230	229	218
SD	5	15	11	24	13

As expected, the females had F0 frequency about 100 Hz higher than those of males. The average F0 was 218 Hz with a mean range of 22 Hz. The SD value was 13 which meant that the average F0 values for females were not much dispersed from the mean. For the females, MW1 is an outlier with consistently low scores.

The difference between females who speak Maate dialect and those who speak Rogoro dialect was tested for significance. Tab. 4.91 gives the results for the females who speak the Maate dialect.

Table 4.91. F0 at Vowel Onset after Stop Consonant /k/ for female informants who speak the Maate dialect of Ekegusii

Maate Women	MW1	MW2	Average
ki	210	223	217
ka	200	206	203
ko	203	192	198
Mean	204	207	206
SD	5	15	10

Tab. 4.91 shows that the average F0 for the vowel after /k/ was 206 Hz within an average range of 19 Hz. The SD for female speakers of Maate dialect is 10. Tab. 4.38 gives the results for female speakers of Rogoro dialect.

Table 4.92: F0 at Vowel Onset after Stop Consonant /k/ for female informants who speak the Rogoro dialect of Ekegusii

Rogoro Women	RW3	RW4	Average
ki	239	257	248
ka	218	215	217
ko	233	215	224
Mean	230	229	229
SD	11	24	17

These females had an average mean of 229 Hz for the vowels after the stop consonant /k/. Average range for these females was 31 Hz with an SD of 17. The females who speak the Rogoro dialect had a bigger dispersion of values from the mean due to the large range and SD.

A test of significance showed that the two groups (Rogoro and Maate dialects) were heterogeneous as the p-value was 0.01. Unlike males, the females who speak the Rogoro dialect had higher values, that is, a mean of 229 Hz as compared to the females who speak the Maate dialect with a mean of 206 Hz.

Lastly on F0 for the vowels after the stop consonant /k/ is Tab. 4.93 which gives the results for the children informants.

Table 4.93: F0 at Vowel Onset after Stop Consonant /k/ for children informants

children	MCF2	MCM1	RCM2	RCF1	AVERAGE
Ki	238	239	220	267	241
Ka	232	233	223	265	238
Ko	244	244	218	266	243
Mean	238	239	220	266	241
SD	6	6	2	1	2

The results give an average F0 for the vowels after the stop consonant /k/ at 241 Hz. RCF2 was an outlier with very high frequencies for all the vowels that come after the stop/k/. The average range for the children was 6 Hz and an SD of 2 implying that the average scores for all the vowels after the stop /k/ were not much dispersed from the group mean.

Children were also grouped into two groups according to the perceived dialect that they spoke. Tab. 4.94 gives the results for the Maate dialect children informants.

Table 4.94: F0 at Vowel Onset after Stop Consonant /k/ for children informants who speak the Maate dialect of Ekegusii

Maate Children	MCF2	MCM1	Average
ki	238	239	239
ka	232	233	232
ko	244	244	244
Mean	238	239	238
SD	6	6	6

The SD for the average scores and individual scores was 6. This low SD value implies that the scores for the group and for the group for each of the instances measured were heterogeneous. The average for Maate children for F0 of vowel after the stop /k/ was 238. These were compared with the children that speak Rogoro dialect on Tab. 4.95.

Table 4.95: F0 at Vowel Onset after Stop Consonant /k/ for children informants who speak the Rogoro dialect of Ekegusii

Rogoro Children	**RCM2**	**RCF2**	**AVERAGE**
ki	220	267	244
ka	223	265	244
ko	218	266	242
Mean	220	266	243
SD	2	1	1

With an average mean of 243 Hz and a standard deviation of 1, the results show that the scores for the Rogoro dialect children were very close together. On a closer look, the scores for RCM2 were lower by over 40 Hz for each vowel sound investigated. Considering the other children too, RCF2 was a clear outlier with the highest scores for all the vowels investigated. Tab. 4.96 gives the summary for the children informants that speak the Maate dialect.

Table 4.96: F0 at Vowel Onset after Stop Consonant /k/ for children informants who speak the Maate dialect of Ekegusii

Maate Children	MCF2	MCM1	Average
ki	238	239	239
ka	232	233	232
ko	244	244	244
Mean	238	239	238
SD	6	6	6

The SD for the Maate dialect children was 6 indicating a minor dispersion from the group mean. The average F0 for this group was 238 Hz. Though the average for Maate dialect children was lower than that for the Rogoro dialect children, a test of significance yielded a p-value of 0.1 which was far higher than the acceptable statistical significance of $p<0.05$. The conclusion one can draw from this is that there was no significant difference between the children from the two dialects in relation to the fundamental frequency of the vowels following the stop consonant /k/.

F0 values at the beginning of the vowel after the stop consonant show significant differences for place of articulation where the average value was highest with vowels following labial stops having the values followed by velars and lastly those following alveolar stops. This was the consistent pattern followed by all the groups except the children who had the vowels following velar stops with the highest F0 values followed by those coming after labial stops and lastly the ones following alveolar stops.

The differences were also significant for gender as expected due to the different anatomical configuration between males and females. Children values were significantly higher than those of the males where $p<.05$ but not significantly different with the results for females.

4.2.4 Burst intensity/amplitude

Burst intensity of the stop consonant measures the loudness of a stop consonant at burst. Amplitude basically measures how far a sine wave departs from its baseline value and also the amount of energy expended in the process. A sound wave is built by the air particles and how they move depending on the variations of air pressure as a result of wave adjustments made by articulatory organs as explained by the source-filter theory. In this study, the burst intensity is measured at the start of frication/burst after stop occlusion.

Spectrograms and waveforms like Fig. 4.73 for the second male informant (RM2), display how overall intensity of a sound rises and falls as determined by the Root Mean Square (RMS) amplitude of the wave.

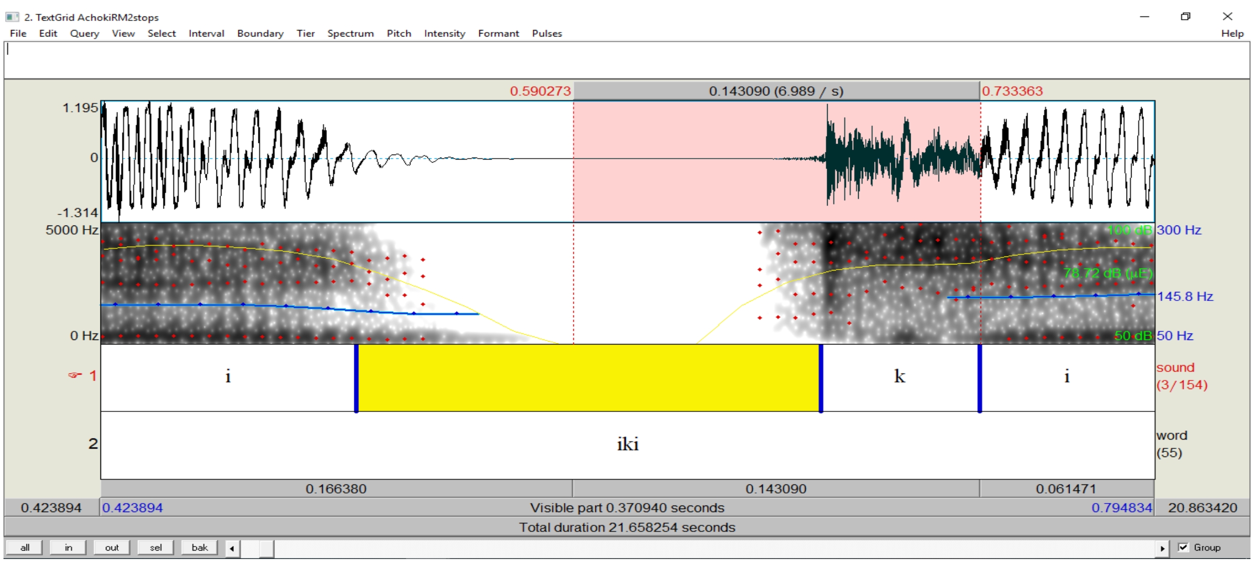


Figure 4.73: Waveform and spectrogram for the stop consonant /k/

We can clearly identify the intensity curve that is marked as a yellow line on Fig. 4.73. For stops, this intensity keeps rising from the point of stop closure, when the intensity line drops to the floor then keeps rising to the point when voicing of the vowel following a stop sets in unlike for vowels where the intensity reduces over the course of the sound.

Tab. 4.97 gives a summary for the intensity of the stop for adult males.

Table 4.97: Stop Consonants burst intensity for males

Stop/vowel	**RM1**	**RM2**	**MM3**	**MM4**	**Average**	**SD**
pi	60	82	72	76	73	9
pa	72	81	72	77	76	5
po	65	79	77	77	74	6
Mean	66	81	74	77	74	6
Standard Deviation	6	2	3	1	2	2
Stop/vowel	RM1	RM2	MM3	MM4	Average	SD
ti	62	77	71	73	71	6
ta	63	77	76	73	72	6
to	65	80	74	74	73	6
mean	63	78	74	73	72	6
Standard Deviation	2	2	3	1	1	1
Stop/vowel	RM1	RM2	MM3	MM4	Average	SD
ki	72	79	77	74	75	3
ka	60	77	79	73	72	8
ko	61	82	79	75	74	9
Mean	64	79	78	74	74	7
Standard Deviation	7	3	1	1	2	3

The males displayed low SD values for the burst intensity for stops. This is translated to mean that the values were not scattered much but just close together. There was equally no significant difference due to place of articulation of the stop consonants. Between /p/ and /t/ p=0.44, between /p/ and /k/ p=0.5. These were far higher than the mathematical threshold of 0.05 and as such, they were not significant.

Tab. 4.98 gives the burst intensity results for the females.

Table 4.98: Stop Consonants burst intensity for females

Stop/vowel	MW1	MW2	RW3	RW4	Average	SD
pi	66	68	77	76	72	6
pa	70	70	72	78	72	4
po	65	70	75	69	70	4
mean	67	70	74	74	71	4
Standard Deviation	3	1	3	5	1	2
Stop/vowel	MW1	MW2	RW3	RW4	Average	SD
ti	69	68	71	67	69	2
ta	64	70	72	74	70	4
to	65	75	72	75	72	5
mean	66	71	72	72	70	3
Standard Deviation	3	4	1	4	2	2
Stop/vowel	MF1	MF2	RF3	RF4	Average	SD
ki	65	72	64	67	67	3
ka	66	69	69	65	67	2
ko	63	70	66	65	66	3
Mean	65	70	66	66	67	2
Standard Deviation	2	1	3	1	1	1

The scores for adult females only had a significant difference when comparing /t/ with /k/ with p=0.003. The other scores were not significant. For dialectal differences, Rogoro dialect speakers had consistent higher values as compared to Maate dialect speakers. This was significant with a p-value of 0.001 for /p/, 0.02 for /t/ and 0.05 for /k/. In general, there was a distinction in the burst intensity for stop consonants for females attributed to dialectal difference. This general trend was discernable for the results of children on Tab 4.99 where speakers of Rogoro dialect had louder bursts than those who spoke Maate dialect.

Table 4.99: Stop Consonants burst intensity for children

Stop/vowel	MCF2	MCM1	RCM2	RCF2	Average	SD
pi	72	72	82	88	79	8
pa	74	71	84	86	79	7
po	77	76	83	86	80	5
mean	74	73	83	87	79	7
Standard Deviation	2	3	1	1	1	1
Stop/vowel	MCF2	MCM1	RCM2	RCF2	Average	SD
ti	79	80	84	83	81	3
ta	73	73	85	86	79	7
to	74	74	76	80	76	3
mean	75	76	82	83	79	4
Standard Deviation	3	4	8	6	3	0

Stop/vowel	MCF2	MCM1	RCM2	RCF2	Average	SD
ki	78	78	87	84	82	5
ka	71	91	83	83	82	8
ko	71	69	74	82	74	6
Mean	73	79	81	83	79	4
SD	4	11	7	1	5	4

There was no significant difference in the scores of the children to separate the stop consonants in terms of place or manner of articulation. The difference between /p/ and /t/ was $p=0.44$ and between /p/ and /k/ was $p=0.5$ which are not statistically significant.

For dialectal difference, children speakers of Rogoro dialect had louder bursts as compared those who speak Maate dialect. The T-test scores were: /p/ had $p=0.001$ (highly significant), /t/ had $p=0.001$ and /k/ had $p=0.04$.

Against expectations from the literatures, the adult male informants had louder bursts than the female counterparts for all the three stop consonant bursts. The difference between /p/ and /t/ for the males was $p=0.02$, $p>0.05$ for the females and also $p>0.05$ for children on a T-test. The difference between /p/ and /k/ at burst was not significant for adult males and children but very significant for adult females at p=0.0003. Also, the difference between /t/ and /k/ for males and for children was not significant but for the females it was significant at p=0.01.

All along, males had louder bursts than the females and children had the loudest bursts for all three stop consonants. The difference between the genders was significant between /p/ at p=0.01, between /t/ at p=0.0002 and between /k/ at 0.0001 on a T-test. Age was also a factor where children had louder bursts than adults.

Another variation tested was dialect. Adult male informants had no significant difference in the burst intensity for all the three stop consonants. But for the females /p/ and /t/ were significantly louder for speakers of Rogoro dialect as compared to speakers of Maate dialect. /k/ was not significantly different when comparing the speakers of the two dialects. For children, just like females, /p/ was significant at 0.0004 and /t/ was significantly different at 0.008 but /k/ was not significantly different. In all the significant differences, children who speak Rogoro dialect had louder bursts than their Maate counterparts.

4.2.5 Coarticulation and locus equations

Locus equations for each of the three EkeGusii stops /p/, /t/ and /k/ are described for adult males and adult females sampled for this study. Consistently, results indicated that locus equation slopes are greatest for /k/, followed by /p/ and least for /t/. The y-intercept is generally greatest for /t/, followed by /k/, with the lowest intercept characterizing /p/. These general observations are clearly illustrated in the tables and graphs below.

4.2.5.1 Results for /p/

The following are results for male speakers for the bilabial plosive /p/. Tab. 4.100 displays the values for male informants as a group.

Table 4.100: Locus equation for voiceless stop /p/ of four EkeGusii male speakers

Phoneme	slope	y-intercept	r^2
p	0.944	198	0.9138

The equation on Tab. 4.100 indicates a steep slope that nears 1.0 with a positive y-intercept and r^2 of 0.9. This can be illustrated better using a graph as in Fig. 4.74.

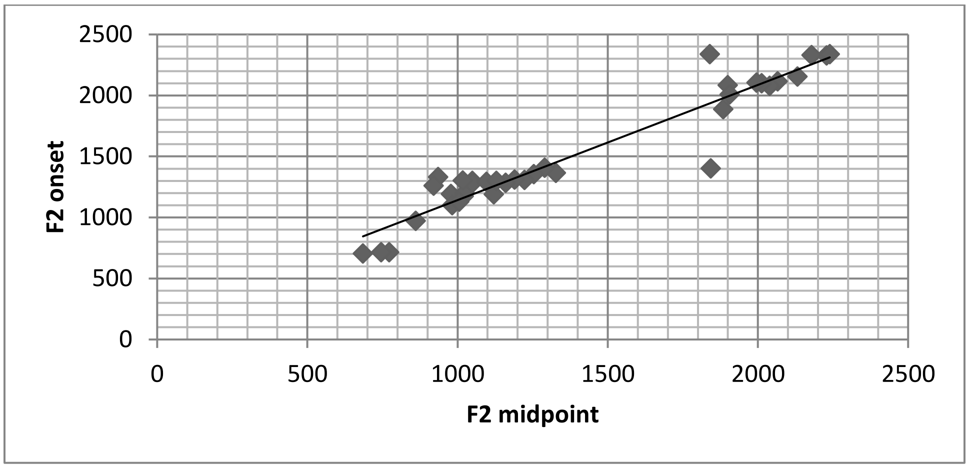
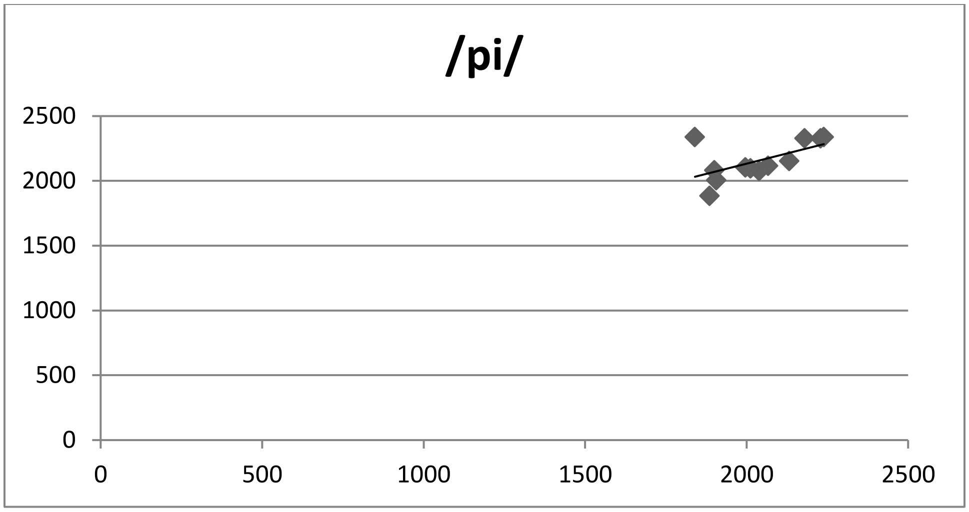
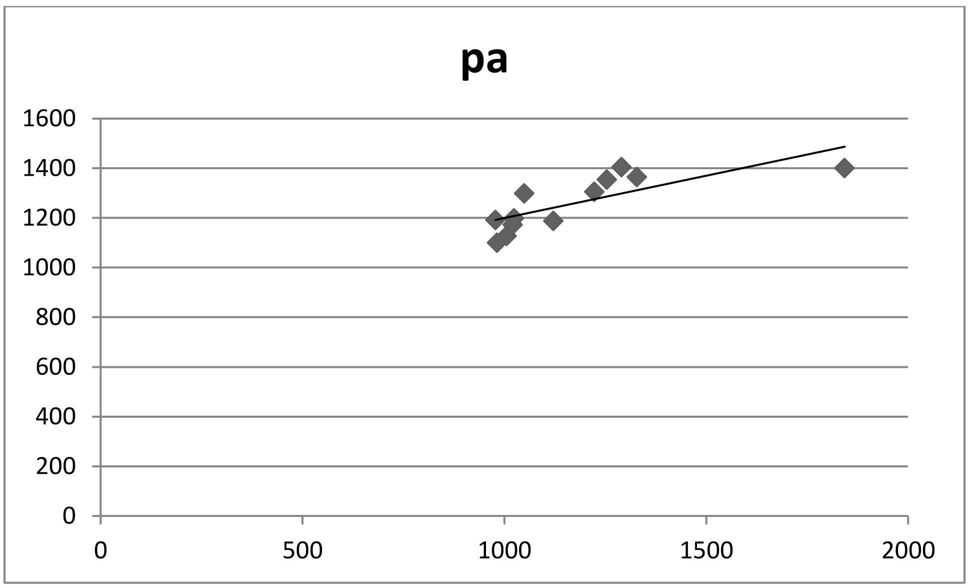


Figure 4.74 Locus equations, with plotted tokens and regression line for male subject's /p/.

All the tokens for the male informants plotted on the graph on Fig. 4.74 showed a steep slope that was an indicator of stop and following vowel coarticulation. That is, there was a close similarity of F2 onset values to F2 midpoint values for the vowels following /p/ for the male speakers. The vowels in CV sequence here are /i/, /a/ and /o/. Each of the vowels could be influenced differently by the stop consonant /p/. The plotted tokens and regression lines for separate vowels for male speakers indicated locus equation variations. Fig. 4.75a, b and c give the locus equations, plotted tokens and linear regressions for the four male subjects.


/pi/
2500
2000
1500
1000
500
0
0
500
1000
1500
2000
2500


pa
1600
1400
1200
1000
800
600
400
200
0
0
500
1000
1500
2000

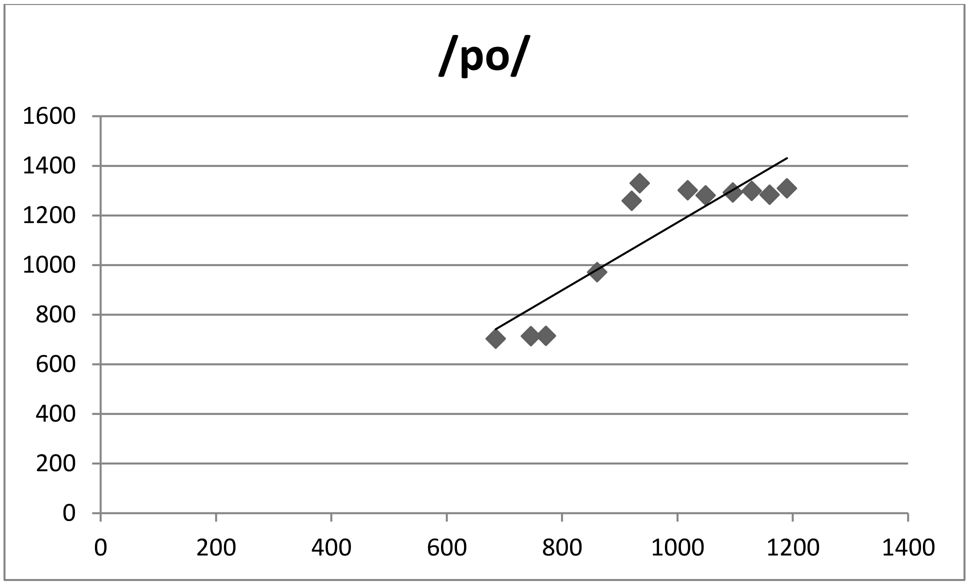


Figure 4.75 a, b, c: Locus equation, with plotted tokens and regression line for male subject's /pi/, /pa/ and /po/.

The regression line is steepest for /po/ with slope at 1.365 and y-intercept at -193.64 meaning that /po/ for males showed higher degree of coarticulation than /pi/ which followed with a slope of 0.631 and the one with least slope is /pa/ with a slope of 0.34. This confirms the idea that F2 rise and fall is also dependent on the following after the stop consonant.

The following are the results for female informants for this study.

Table 4.101: Locus equation for voiceless stop /p/ of four EkeGusii male speakers

Phoneme	slope	y-intercept	r^2
p	1.0806	-37.076	0.99

The table above can be displayed better in a graph showing the locus equation, plotted tokens and regression line as in Fig. 4.76.

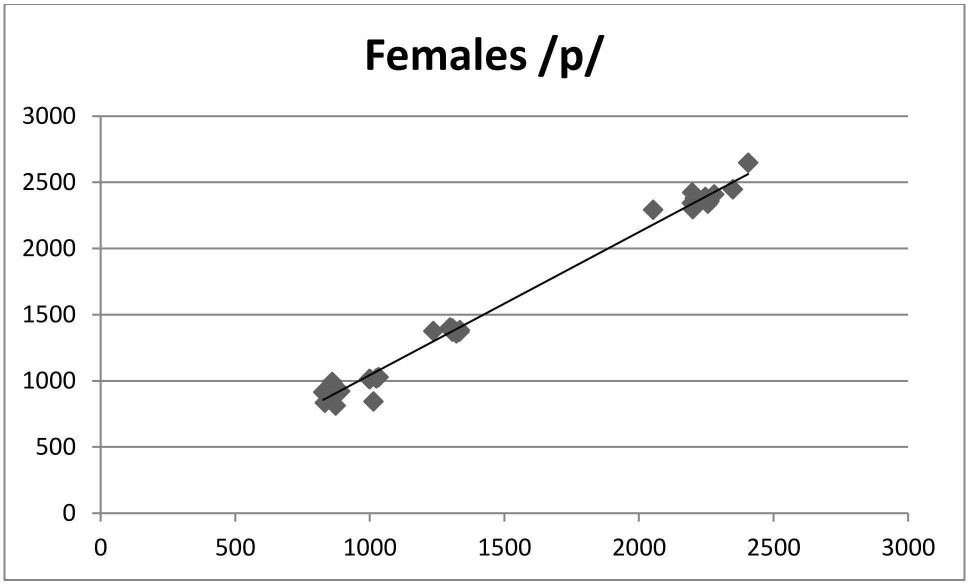
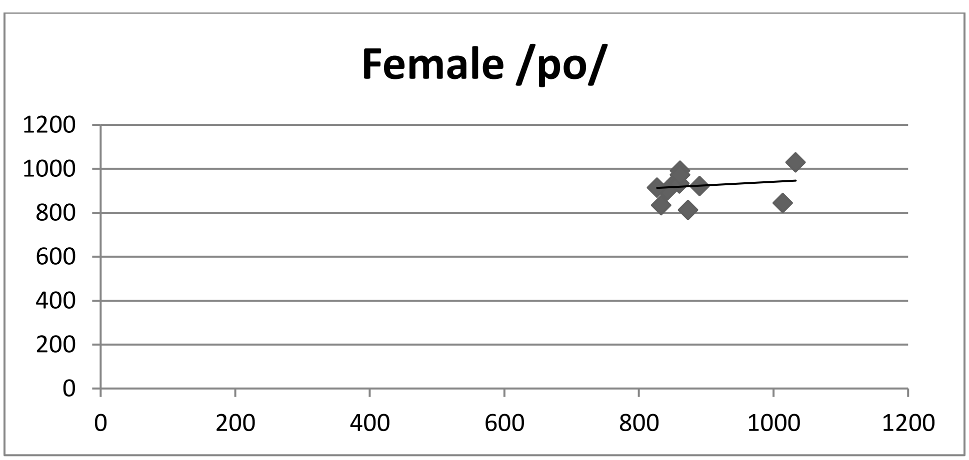
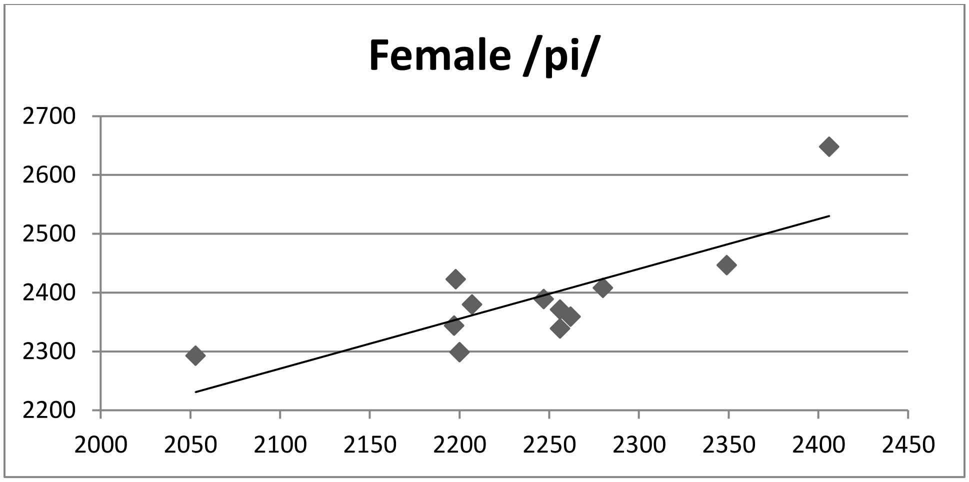


Figure 4.76: Locus equation, with plotted tokens and regression line for female subject's /p/.

The slope was slightly above 1.0 with a y-intercept of -37 and an r-squared value of 0.99. This shows that the slope was steeper than those of the males and that the stop consonant /p/ was coarticulated with following vowels. Just like the males above, coarticulation levels varied depending on the vowel coming after the bilabial stop. In Fig. 4.77 a, b and c locus equations, y-intercept and regression lines for /p/ separately with vowels /i/, /a/ and /o/ as they vary in slope steepness are displayed.





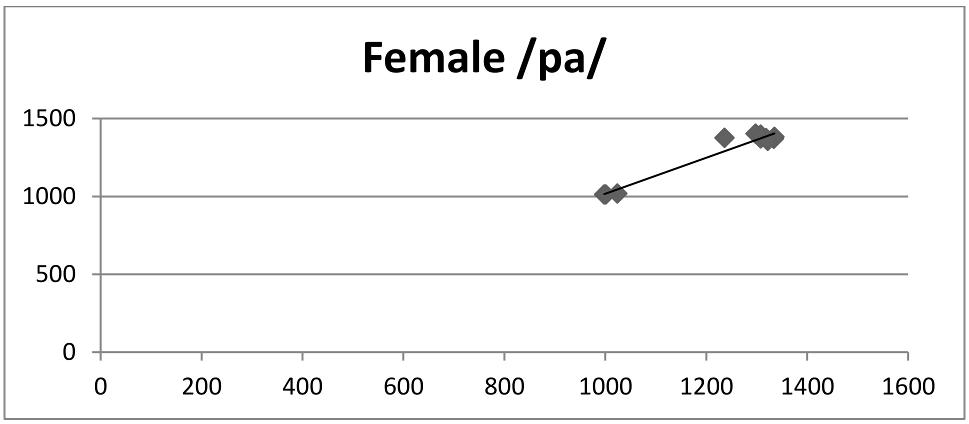


Figure 4.77 a, b, c: Locus equation, with plotted tokens and regression line for female subject's /po/, /pi/ and /pa/.

The distinguishing element for /p/ is that following vowels influence the slope and y-intercept points differently. The slope is steepest with /pa/ with a negative y-intercept. The negative y-intercept means that F2 onset values are generally lower than the corresponding F2 midpoint values. Locus equations for /p/ tend to have low y-intercept values that but they are not always negative as seen in Fig. 4.77(c) above.

These results support the assertion that there are two types of coarticulation for /p/: lingual and labial. For lingual coarticulation, it seems that the tongue positions itself in anticipation to the height and backness of the following vowel as the preceding /p/ is produced. Labial coarticulation is a carry-over effect from the preceding labial to the following sonorant whereby we see the vowel F2 onset value consistently lower than F2 midpoint value.

4.2.5.2 Results for /t/

In the following section locus equations for the same eight speaker's tokens of /t/ are presented. The graphs and regressions allow us to make observations about the trajectory of the regression line as relates to coarticulation. The following are results for male subjects.

Table 4.102: Locus equation for voiceless stop /t/ of four EkeGusii male speakers

Phoneme	slope	y-intercept	r^2
t	1.0303	-12.27	0.9523

Tab. 4.102 above gives a very steep slope of above 1.0 and a negative y-intercept. This means that in the majority of the tokens, F2 onset values were higher than F2 midpoint values. This is exemplified in the plots on Fig. 4.78.

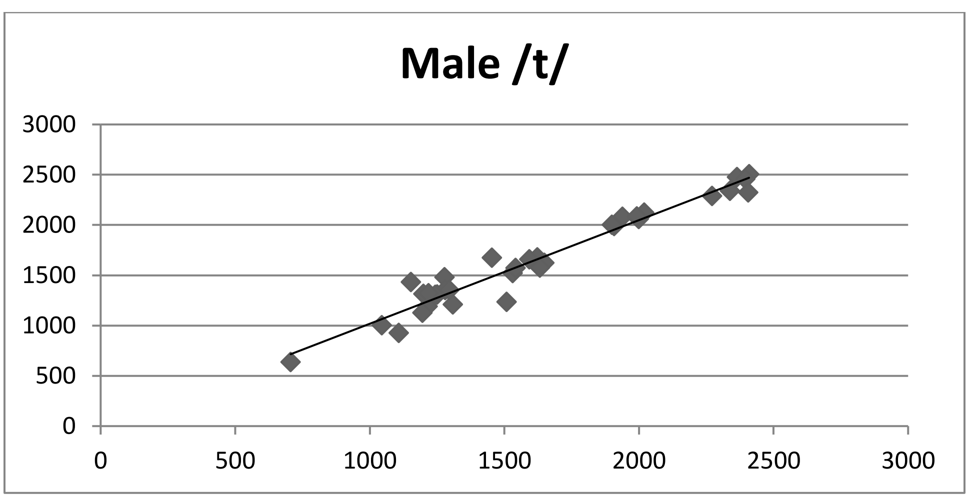
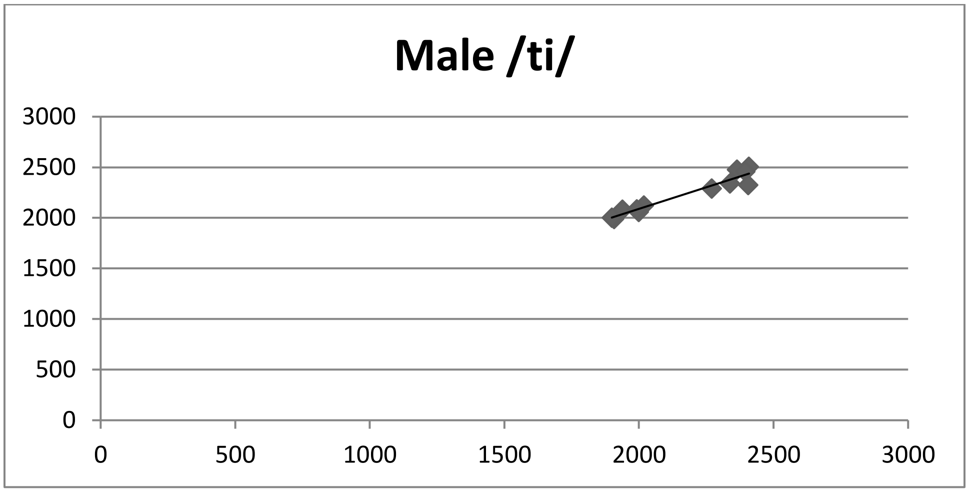
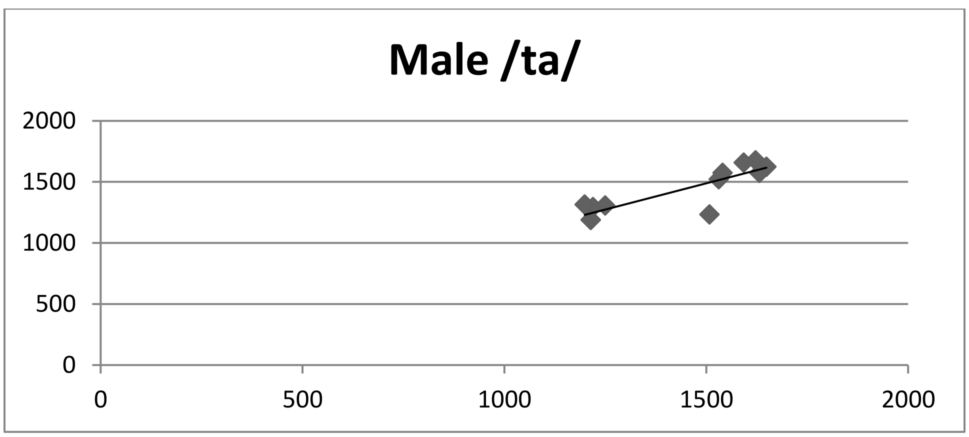


Figure 4.78: Locus equation, with plotted tokens and regression line for male subject's /t/.

From the graph on Fig. 4.78 we can observe that the slope is steeper than that of the same males for /p/ which, though steep, was below 1.0. Apart from this general observation; various CV sequences influenced the F2 trajectory differently for the males depending on the following vowel after /t/ as seen below.





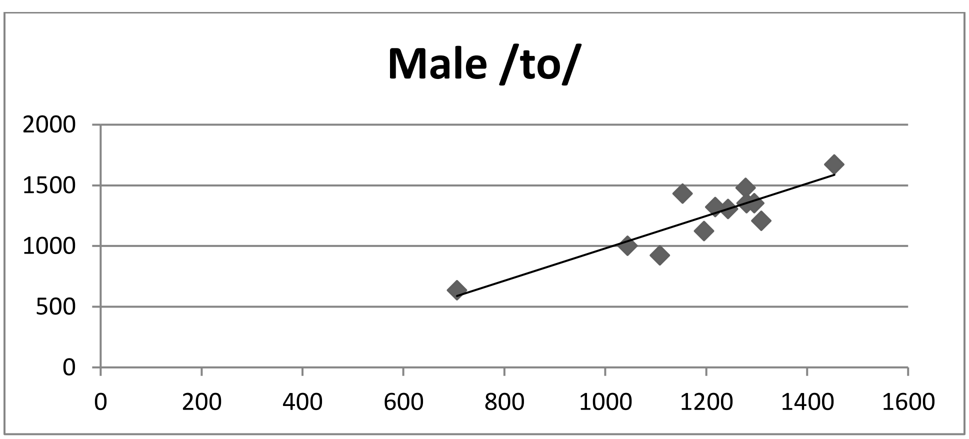


Figure 4.79 a, b, c: Locus equation, with plotted tokens and regression line for female subject's /ti/, /ta/ and /to/.

The slope for /t/ was generally steep for all the three vowel instances. The slope for /t/ was at 0.8526 and y-intercept at positive 384. The values indicate that for /ti/ F2 onset was consistently higher than F2 target value. The difference between F2 onset and F2 midpoint was not large. The slope is slightly steeper for /ta/ with a slope of 0.8584 and a y-intercept value of positive 200. This also indicated a higher level of coarticulation between /t/ and the following vowel. The greatest coarticulation was that recorded for /to/. The slope was at 1.3346, a steep slope of above 1.0. The value for y-intercept was negative 354. The negative y-intercept values show that consistently F2 onset values were lower than the F2 midpoint value.

The following are results for the female speakers.

Table 4.103: Locus equation for voiceless stop /t/ of four EkeGusii female speakers

Phoneme	slope	y-intercept	r^2
t	1.1054	-154.76	0.8654

The slope for the females is steeper than that of the males with negative y-intercept values that are indicative of the idea that F2 onset values were consistently lower than the F2 midpoint values for all tokens. The following graph and plotted tokens on Fig. 4.80 for females illustrates this better.

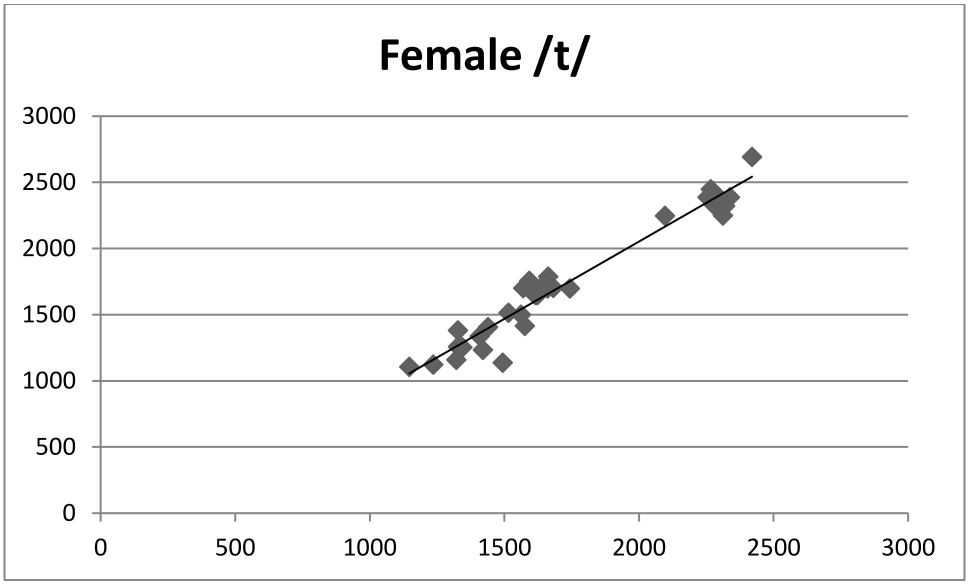
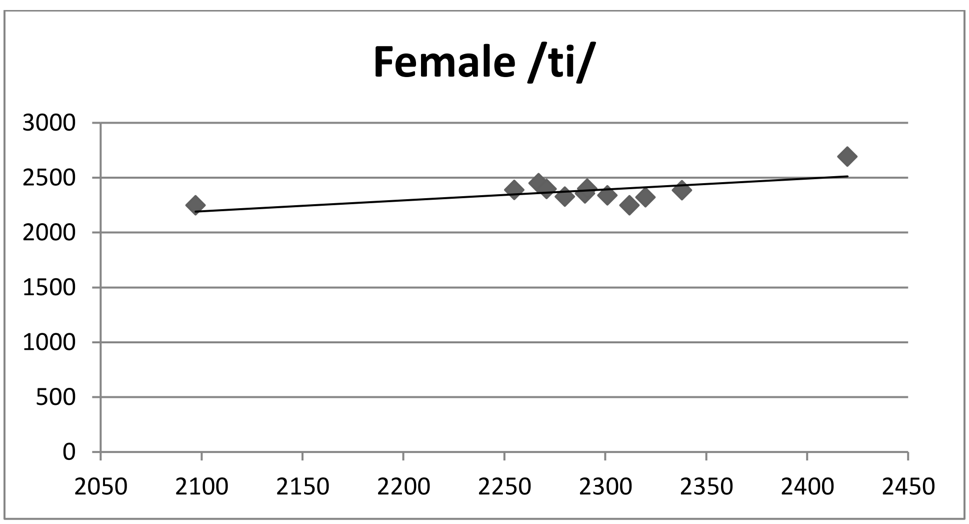
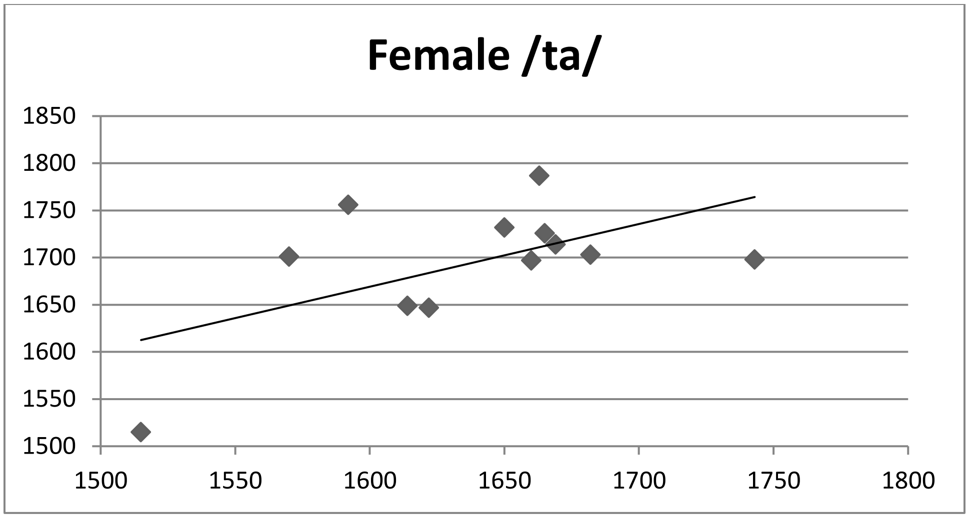


Figure 4.80: Locus equation, with plotted tokens and regression line for female subject's /t/.

Locus equation results posted by female informants are similar to those posted by the male counterparts with a little variation. Fig. 4.81 a, b, and c are locus equation graphs with plotted tokens for each CV sequence as got from the female speakers.





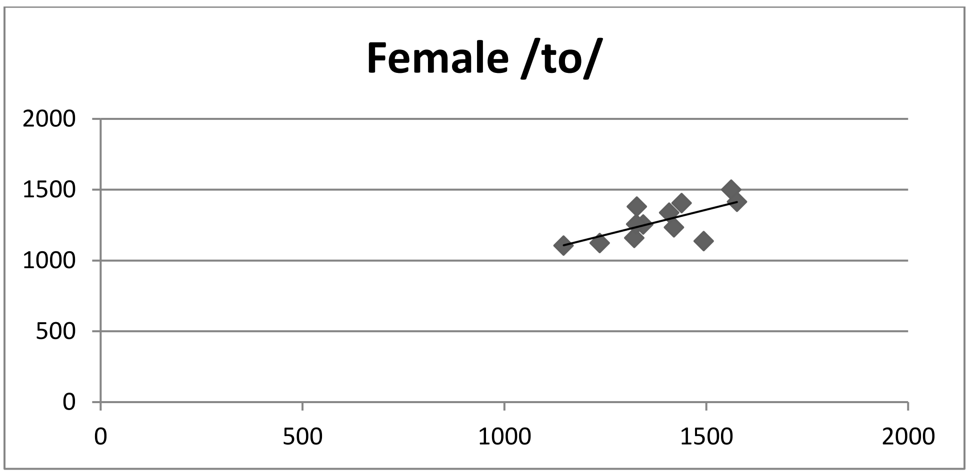


Figure 4.81 a, b, c: Locus equation, with plotted tokens and regression line for female subject's /ti/, /ta/ and /to/.

Females show great variation of coarticulation between an alveolar plosive and following vowel. Females have the greatest disparity between F2 onset and F2 midpoint of vowel following alveolar consonant /t/ for /a/ with a regression line having a less steep slope of 0.665 followed by the slope of /o/ with 0.7117 and /i/ with the steepest slope of 0.9934. It should be noted too that the steeper the slope the lower the y-intercept value.

Generally, the increased coarticulation associated with /t/ is also supported by lower y-intercept values and a steeper slope. For these EkeGusii female and male speakers, a closer proximity between vowel F2 onset and F2 midpoint following alveolar plosive is witnessed. Variations observed in the locus equations as the vowels are changed from /ti/, /ta/ and /to/ reflect the constriction of the oral cavity during the production of the alveolar plosive. As /ti/, /ta/ and /to/ are considered separately for F2 onset and F2 midpoint, characteristic tongue movement from alveolar place of articulation to the target position associated with the following vowel. /t/ affects F2 onset values: for /i/ F2 values are extremely high hence occurring at the leftmost part of the regression lines whereby F2 onset values are less than vowel F2 midpoint values; for the tokens of /a/ vowel, they typically have very high F2 values hence occupying the left-most part of regression lines as seen on Fig. 4.83 and Fig. 4.85. The low F2 values are consistent with the smaller constriction size of the oral cavity associated with the preceding /t/ plosives. The same oral cavity configuration does not hold for tokens of /i/ and /o/ vowels which are far higher as compared to those of /a/. These F2 loci are typical to the locus equations associated with /t/ in EkeGusii which also attests to the locus equations seen in the literatures.

4.2.5.3 Results for /k/

Having looked at the locus equations data for /p/ and /t/, I will now turn to locus equations for /k/. Generally, locus equations for /k/ have a slope value nearing 1.0 which is indicative of high degree of /k/-V coarticulation. Tab. 4.103 gives the results for the male subjects.

Table 4.104: Locus equation for voiceless stop /k/ of EkeGusii male speakers

Phoneme	slope	y-intercept	r^2
k	0.925	+15.979	0.9519

The slope for /k/ was steep close to 1.0 and a small y-intercept value of positive 16. R-squared value also approximates 1.0. The following graph with plotted tokens for /k/ for male subjects.

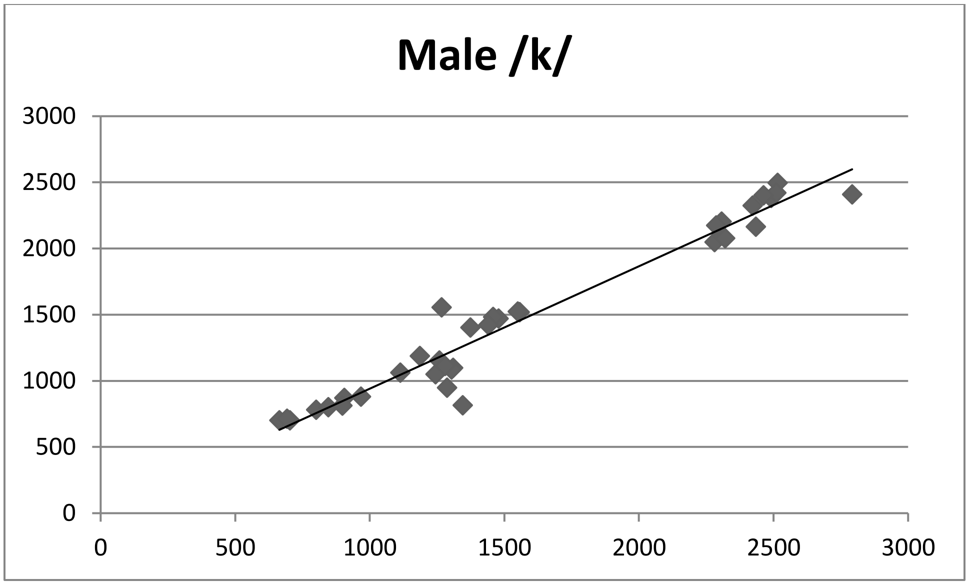
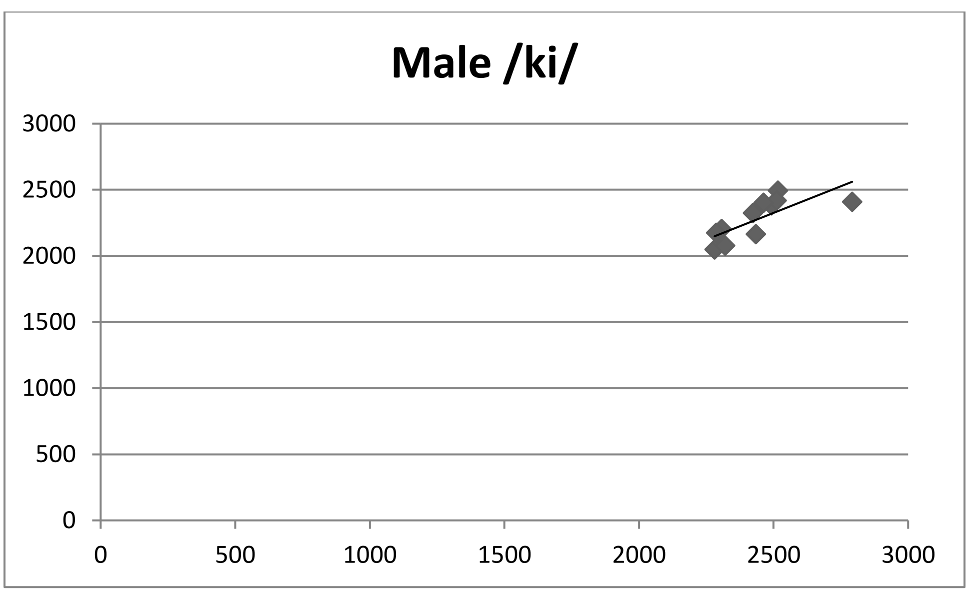
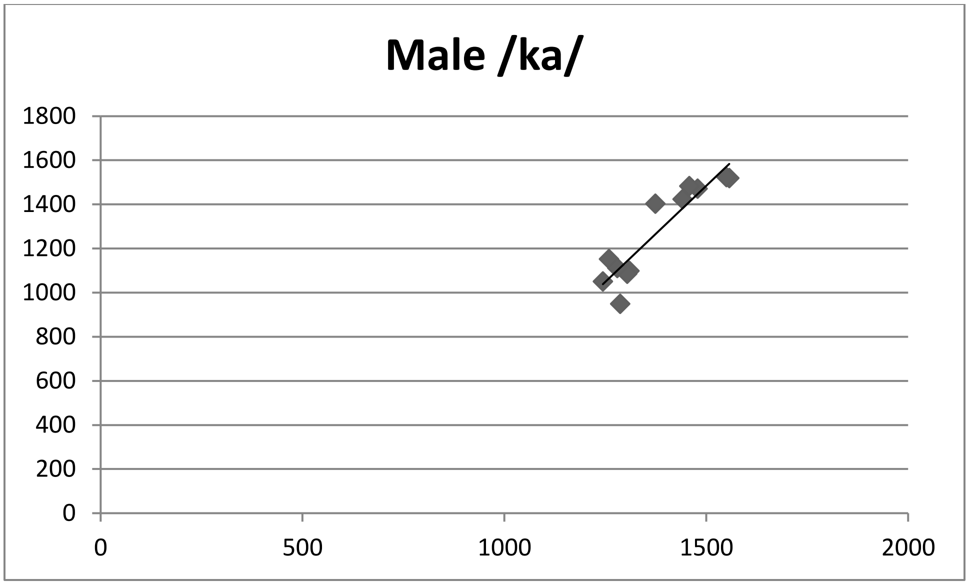


Figure 4.82: Locus equation, with plotted tokens and regression line for male subject's /k/.

However, despite the steep slope posted by the male informants here, the correlation between the F2 onset and F2 midpoint keeps changing since the y-intercept is at about 16 Hz. This means that some tokens have F2 onset values higher than the F2 midpoint. This can be made plain when locus equation plots for each vowel are plotted as in Fig. 4.87 below.





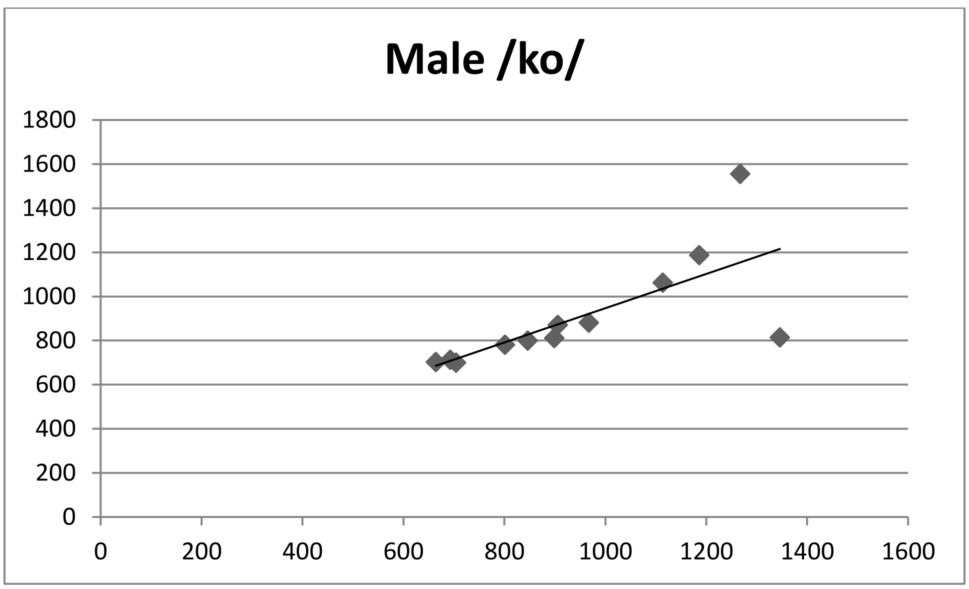


Figure 4.83 a, b, c: Locus equation, with plotted tokens and regression line for female subject's /ki/, /ka/ and /ko/.

The variations in the locus equations for /ki/, /ka/ and /ko/ are indicative of the influence that /k/ has on the following vowel. The slope for /ka/ is so steep indicating a negligible disparity between F2 onset and F2 midpoint. This could be as a result of consonant place of articulation and height of vowel which approximate easily; there is minimal alteration of jaw height and tongue position from the articulation of /k/ to the articulation of /a/. For /ko/ the slope is at 0.777 and /ki/ the slope is 0.8063 all steep slopes suggestive of more coarticulation, in degrees of course.

The following results are for the female subject.

Table 4.105: Locus equation for voiceless stop /k/ of EkeGusii female speakers

Phoneme	slope	y-intercept	r^2
k	0.9539	+54.147	0.965

Tab. 4.105 can graphically be displayed for a better look at the locus equation and regression line in Fig 4.84 below.

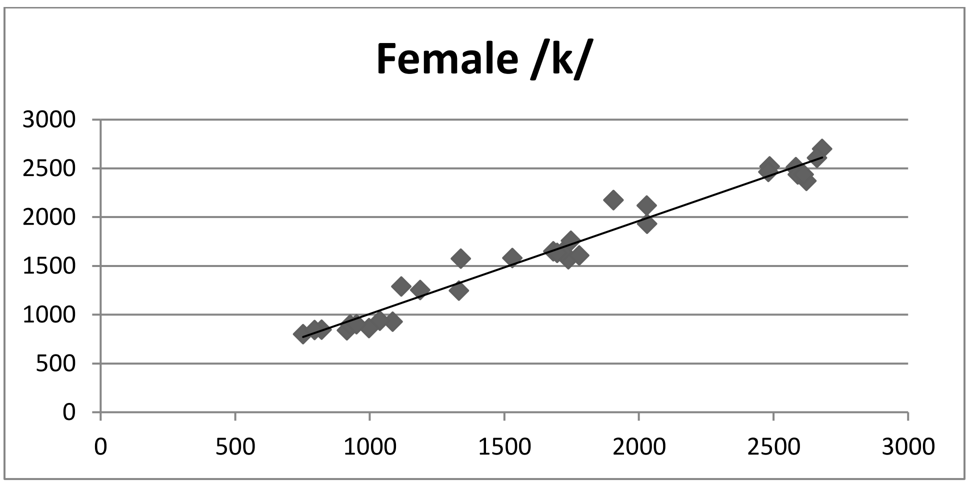


Figure 4.84: Locus equation, with plotted tokens and regression line for female subject's /k/.

The degree of coarticulation for the female speakers is not very different from that of the male speakers as the slope is 0.95 which nears 1.0. Though quite similar, the slopes of female speakers have some subtle differences with those of the males. Somehow, these differences could be taken as cues for gender differentiation for the stop consonant. We can discern the differences between the genders when looking at the separate locus equations for /ki/, /ka/ and /ko/ as in Fig. 4.85.

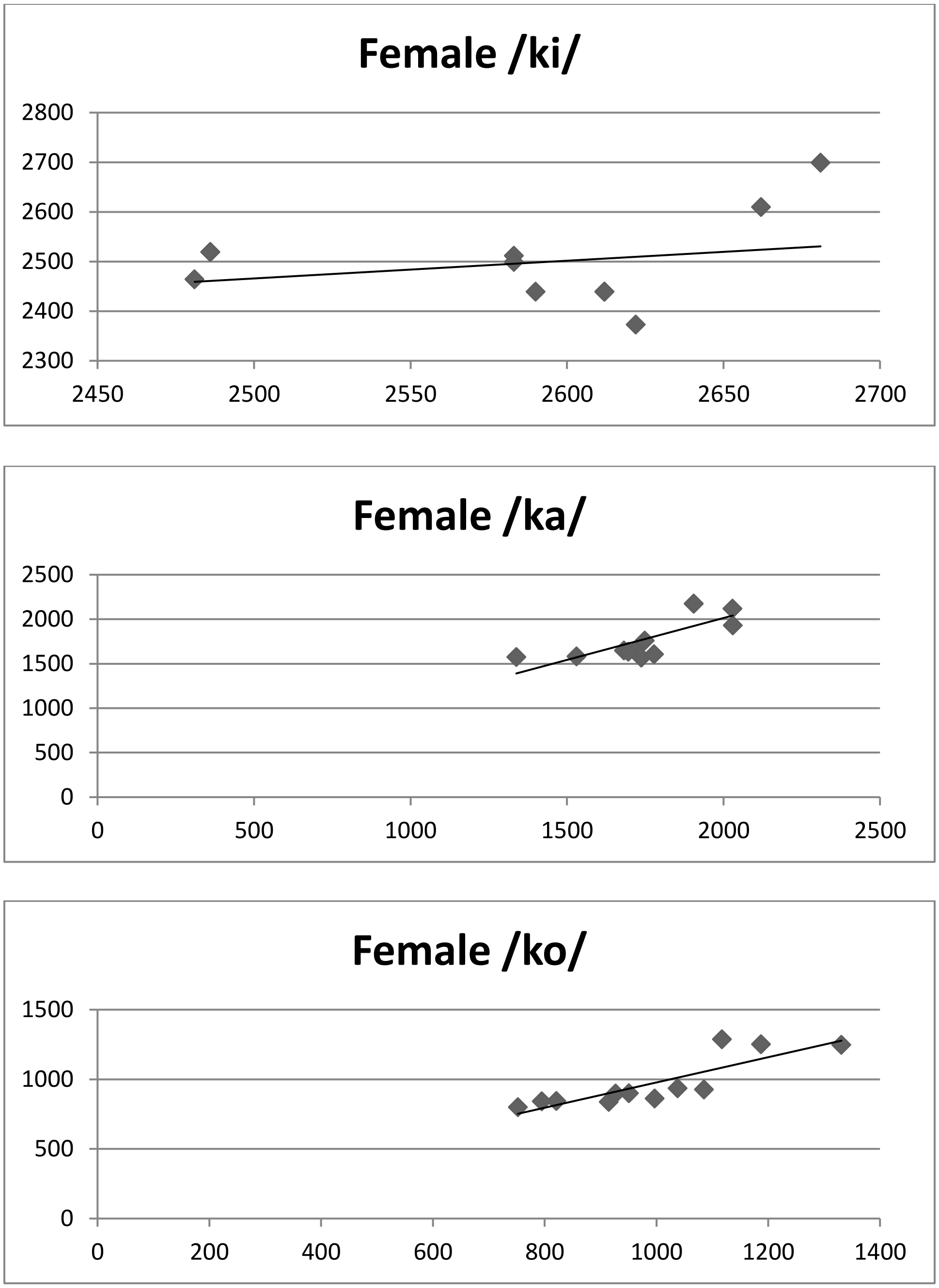


Figure 4.85 a, b, c: Locus equation, with plotted tokens and regression line for female subject's /ki/, /ka/ and /ko/.

For /ki/, the F2 onset following /k/ is generally higher or almost equal to F2 midpoint or target value. This makes the slope to be less steep as an indication of less coarticulation for these female informants unlike the slope posted for the male above. Unlike /ki/, /ka/ has a steep slope of 0.941 and a relatively low positive y-intercept of 130.67. For /ki/ F2 onset value is lower than the F2 midpoint value. There is no big difference between /ka/ and /ko/. The gradient for /ko/ is steep at 0.91.

Fig. 4.86 and Fig. 4.87 displays combined graph for the three stop consonants and their regression lines for the female and male informants.

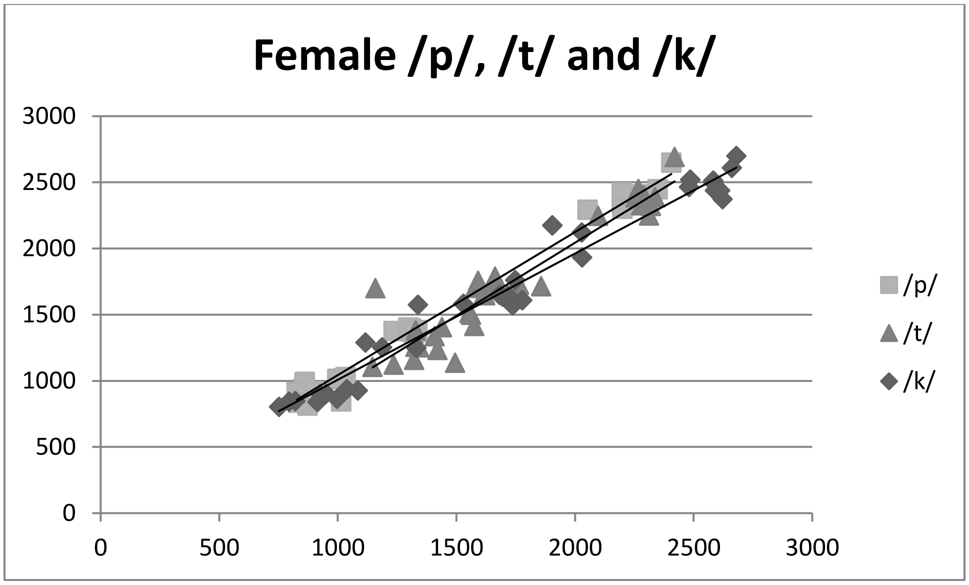


Figure 4.86: Graphic summary of locus equations and regression lines for female subject's /p/, /t/ and /k/.

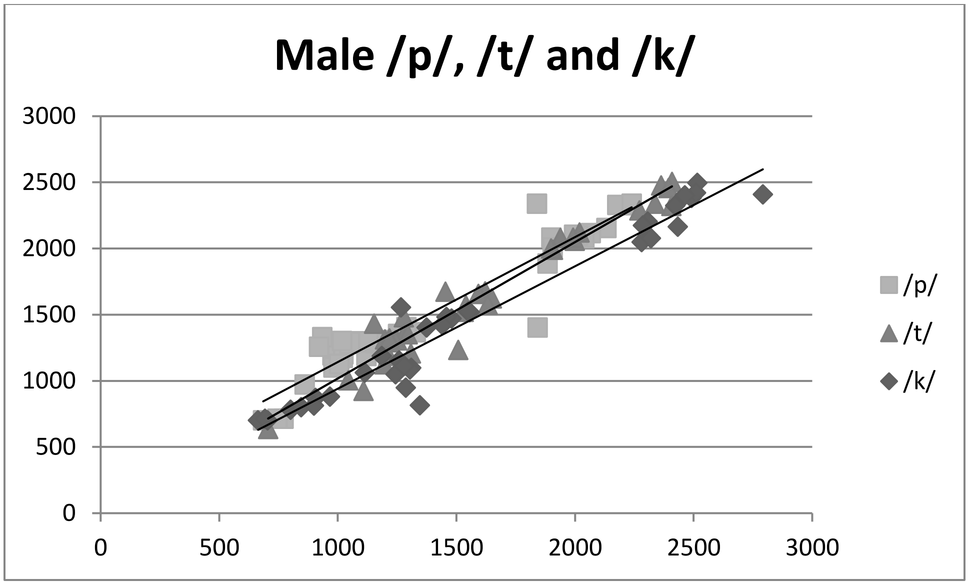


Figure 4.87: Graphic summary of locus equations and regression lines for male subject's across /p/, /t/ and /k plus vowels/.

Female informants had the steepest slope with alveolars /t/ at 1.1 followed by that of bilabials /p/ at 1.0 and the least steep slope for velars /k/ at 0.95. On their part, male informants had the steepest slope with alveolars /t/ at 1.03 followed by bilabials /p/ at 0.944 and the least slope was recorded for the velars /k/ at 0.925. The same order was maintained by the two groups. It should be noted that all the slopes were close to 1.0 indicative of high coarticulation for all the EkeGusii stop consonants.

Despite the subtle differences noted earlier between the values for malles and females, the slopes and regression lines reported for both of them are quite similar. Interspeaker differences can be investigated further to reveal deeper patterns of coarticulaion for EkeGusii stop consonants. However, locus equations for all the female and male informants reveal uniquely similar patterns of EkeGusii CV coarticulation. The isomorphism witnessed attests the patterns that are EkeGusii specific.

To the best of my knowledge, no similar locus equation plots and regression lines exist in the literatures for EkeGusii, or even for other Bantu languages related to EkeGusii. It is hoped that future phonetic studies will allow the comparison of these locus equation data with others. For the sake of this study, we can only observe the patterns of coarticulation as brought out by the locus equations of EkeGusii voiceless stop consonants.

4.3 EkeGusii vowel and stop qualities in running speech

In this section, the vowel qualities (cf. 4.1) and stop consonant qualities (cf. 4.2) are investigated on the backdrop of running speech. Because of the rapidity of running speech, the qualities of the sounds under investigation are affected by the lessened duration and more coarticulation. The same words used in the citation data were the target words in the carrier sentences as this could help eliminate intervening variables that could be caused by having different words.

4.3.1 EkeGusii vowel formants in running speech

The result for the adult male informants for the fundamental frequency (F0), first, second and third formants are seen on Tab. 4.106.

Table 4.106. F0, F1, F2 and F3 results for vowels and their SDs for males

male formants	F0	F0 SD	F1	F1 SD	F2	F2 SD	F3	F3 SD
i	**142**	13	**304**	17	**2104**	269	**2983**	177
e	**114**	15	**379**	27	**1935**	205	**2799**	133
ɛ	**105**	7	**422**	28	**1768**	225	**2702**	257
a	**133**	8	**544**	60	**1428**	172	**2555**	581
ɔ	**126**	6	**434**	46	**1372**	191	**2639**	161
o	**106**	8	**394**	45	**1276**	96	**2672**	105
u	**110**	7	**304**	24	**1444**	136	**2556**	127

The fundamental frequency averages for males range between 106 Hz for /o/ to 142 Hz for /i/. The front vowels /i/ and /e/ have higher SDs of 13 and 15 respectively. This means that the dispersion from the mean was higher for the first two front vowels as compared to the other vowels with SDs between 6 and 8. F0 values indicated that they were close together as evidenced by the small SD.

From the data on Tab. 4.106, values for F2 show very high SDs. This means that F2 was much dispersed from the average considering averages for each informant. Apart from F2 for males being scattered, formant results for the vowel sound /u/ with high F2 of 1444 Hz could make it pass for a central vowel just like /a/ with F2 of 1428 Hz.

Tab. 4.107 gives the results for adult females for the fundamental frequency, F1, F2 and F3 with their SDs.

Table 4.107: *F0, F1, F2 and F3 results for vowels and their SDs for females*

vowels	F0	F0SD	F1	F1SD	F2	F2SD	F3	F3SD
i	**239**	19	**333**	25	**2245**	158	**3079**	278
e	**214**	30	**440**	27	**2006**	130	**2914**	156
ɛ	**192**	29	**496**	29	**1864**	100	**3014**	256
a	**209**	74	**632**	39	**1758**	138	**2955**	288
ɔ	**249**	24	**538**	22	**1453**	191	**2863**	329
o	**211**	15	**456**	22	**1291**	126	**2798**	288
u	**195**	40	**361**	39	**1391**	69	**2661**	144

Adult females have larger SDs for all measurements taken here. This indicates that values for females are more spread around the mean than those of males. Females too, as expected, had higher frequency values than those for males. Fundamental frequency averages for female ranges between 192 Hz for / ɛ/ to 249 Hz for / ɔ/. The central vowel/a/ had the highest SD of 74. This means that the dispersion from the mean was high for the vowel /a/ as compared to the other vowels with SDs between 15 and 40. The differences among values of males and among the values of females after a Chi-test had a p-value of p>0.05. The differences were not statistically significant but as a result of randomness in the population.

From the data on Tab.4.106 and Tab. 4.107, the values for F2 and F1 show a range of standard deviations that make vowel charts for various informants to have variability yet within a given range. This is exemplified in scatter plot charts for the informants as follows.

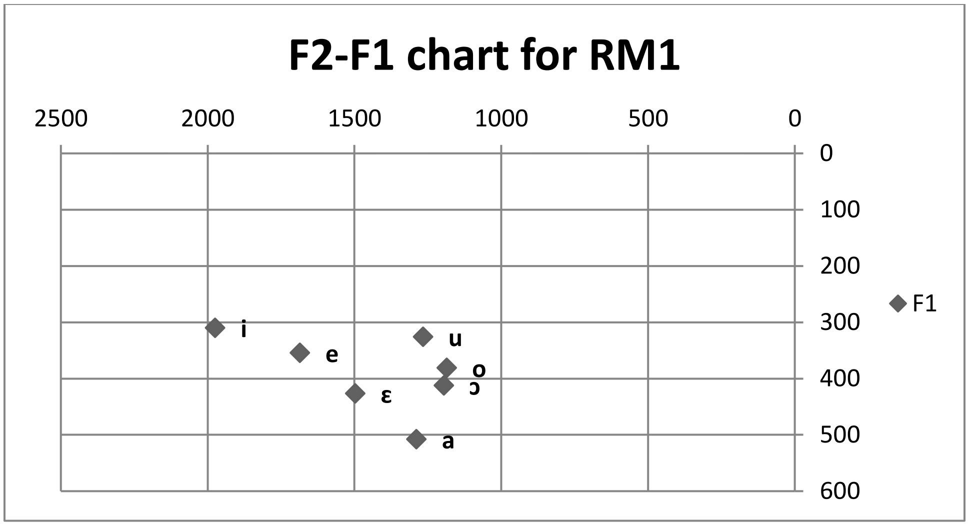


Figure 4.88a: F2-F1 plot for male informant RM1

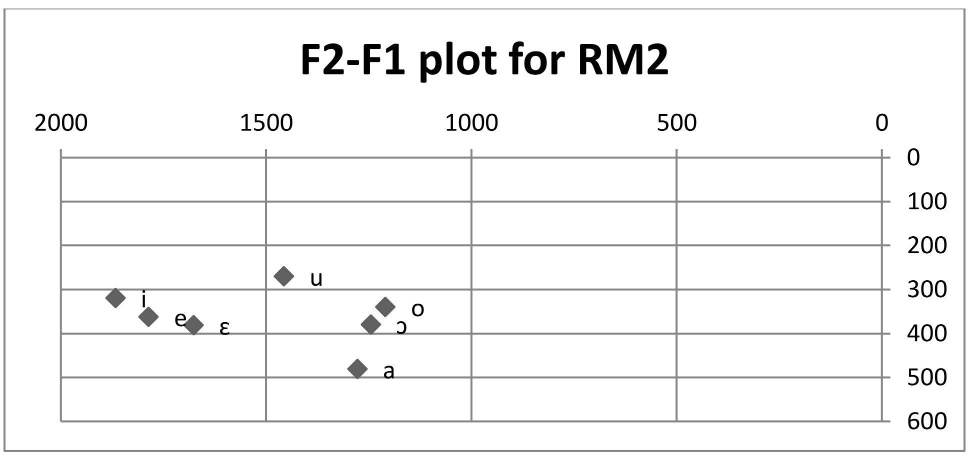


Figure 4.88b: F2-F1 plot for male informant RM2

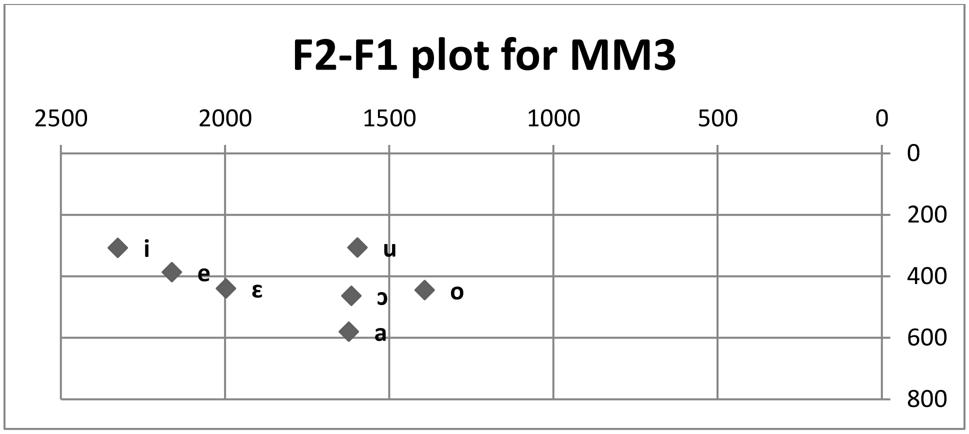


Figure 4.88c: F2-F1 plot for male informant MM3

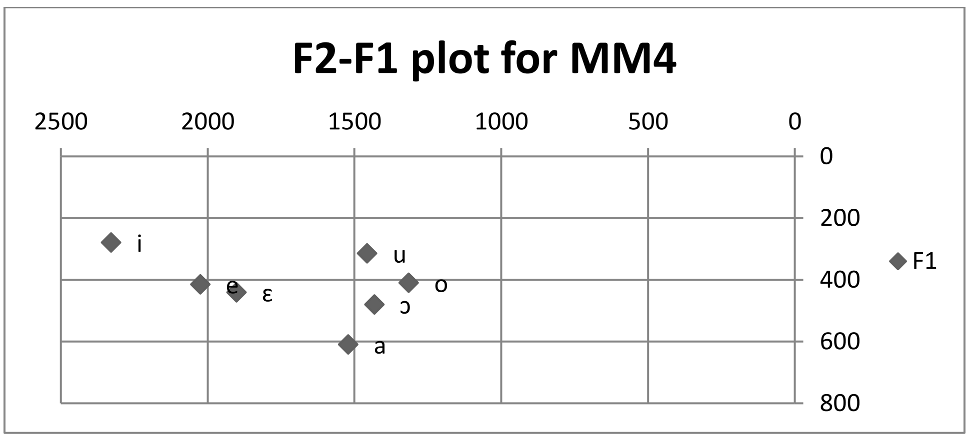


Figure 4.88d: F2-F1 plot for male informant MM4

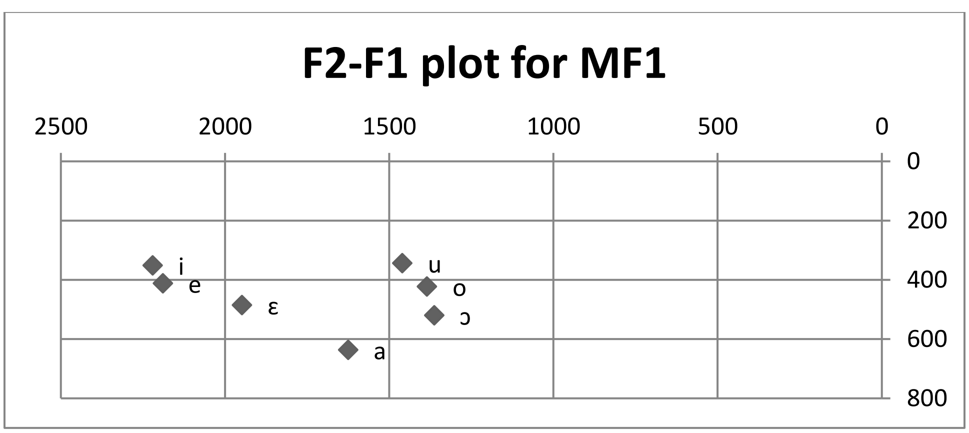


Figure 4.88e: F2-F1 plot for female informant MF1

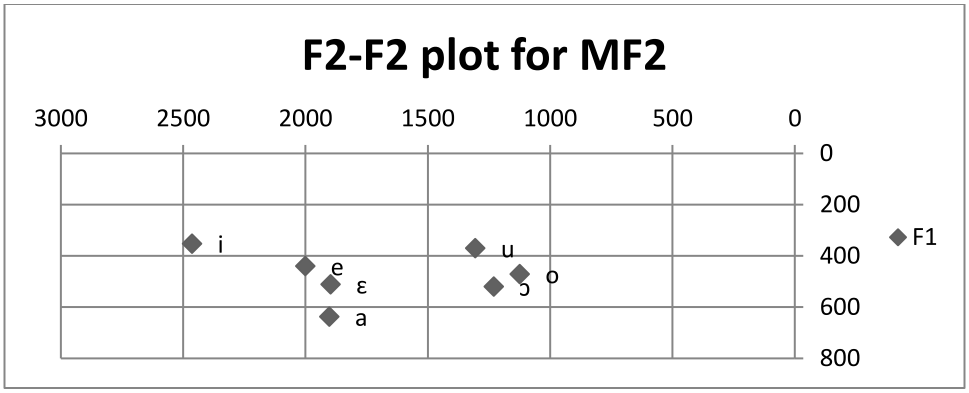


Figure 4.88f: F2-F1 plot for female informant MF2

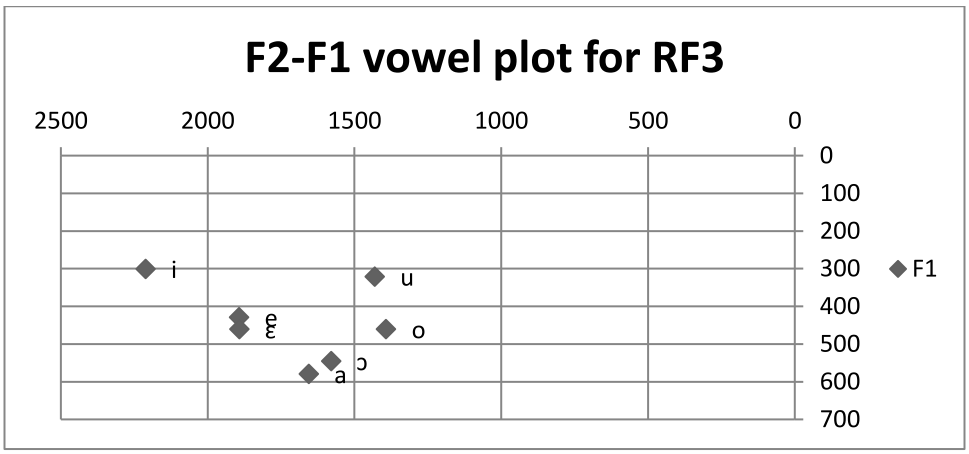


Figure 4.88g: F2-F1 plot for female informant RF3

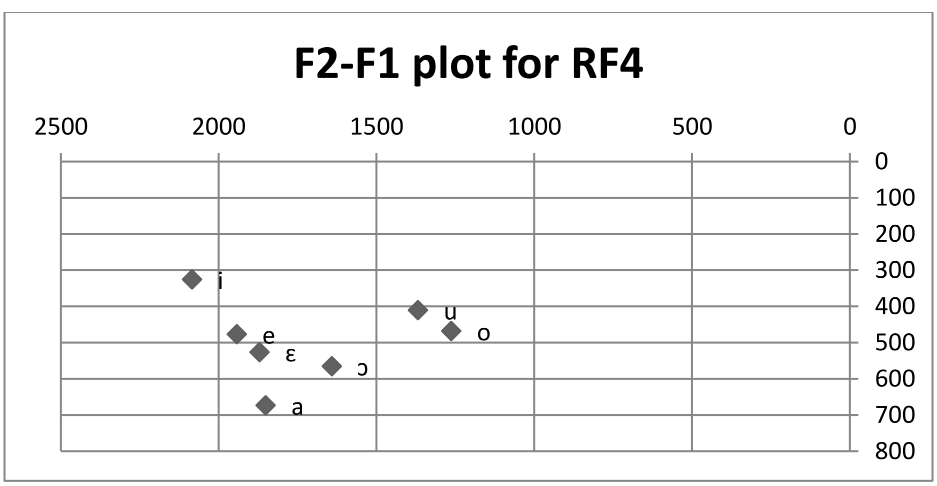


Figure 4.88h: F2-F1 plot for female informant RF4

One remarkable thing about the results from vowels in running speech (Fig. 4.88a-h) was that the general triangular shape can be discerned for each informant. They indicated that /i/ was the front-most vowel with the highest F2 values for all the informants, making it the highest and front most placed on the chart. The other vowels fall into place as expected in the approximate spaces as seen (cf. 4.1) from the data in citation form, that is, /i/ as the front most vowel and highest placed on the chart, it is followed by /e/ and /ɛ/ in that order. The central vowel /a/ was the lowest placed vowel on the chart. For back vowels, /u/ was placed highest for all the talkers followed by /o/ which for the majority of informants (males and females alike), it had the lowest F2 value translated to be the back most placed vowel. It is then followed by /ɔ/. There was no single instance where we had an informant whose vowels were arranged in a different order.

For talkers like RM1, vowels are close together, for front vowels /i e ɛ/, back vowels /u o ɔ/ and low central vowel /a/. The low central vowel for this speaker has low F2 which could make it pass for a back vowel. Also, the back vowels were closer to each other than the front vowels are. The same pattern is replicated by all the other male talkers and even the female and children though on a higher frequency with a few outliers.

Tab. 4.108 gives the F0 and formant summaries for the males with their standard deviations.

Table 4.108: *F0, F1, F2 and F3 results for vowels and their SDs for males*

vowels	**F0**	**F0 SD**	**F1**	**F1 SD**	**F2**	**F2 SD**	**F3**	**F3 SD**
i	**142**	13	**304**	17	**2104**	269	**2983**	177
e	**114**	15	**379**	27	**1935**	205	**2799**	133
ɛ	**105**	7	**422**	28	**1768**	225	**2702**	257
a	**133**	8	**544**	60	**1428**	172	**2555**	581
ɔ	**126**	6	**434**	46	**1372**	191	**2639**	161
o	**106**	8	**394**	45	**1276**	96	**2672**	105
u	**110**	7	**304**	24	**1444**	136	**2556**	127

Each of the vowels for males could be located within a given range as expected. The deviations witnessed on Tab. 4.108 can be seen on the F2-F1 scatter plot for the adult male informants.

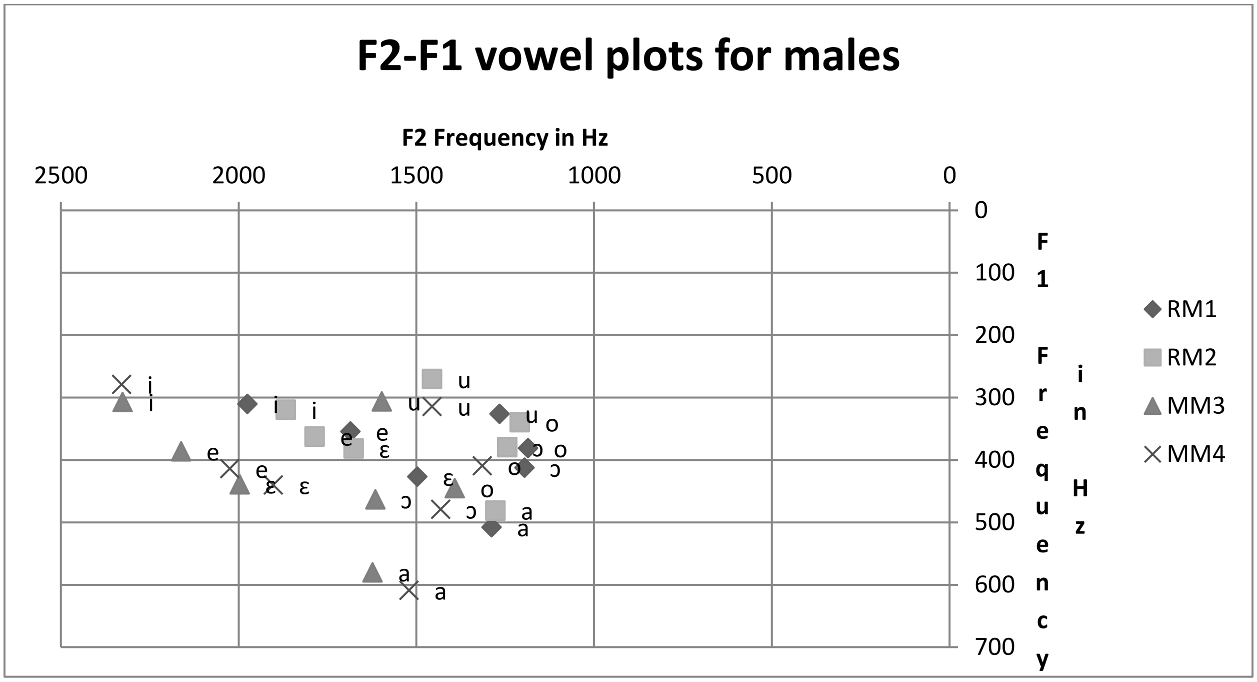


Figure 4.89: F2-F1 multiple plots for male informants

The results for connected speech follow the same trajectory as those for the vowels in citation form. However, there is a consistent difference between those extracted from word-lists where the values for both F1 and F2 are slightly higher than F1 and F2 values extracted from the carrier sentences. The difference was further tested using the Student's T-test. The difference between the F2 for word-lists and the F2 for carrier sentences was not significant with a p-value of 0.02. This means that the difference was just a random chance. The difference between the F1 of word-lists and F1 of carrier sentences had a very significant value of 0.0005. This implies that the difference between word-lists and carrier sentence vowels was only realizable on F1.

Fig. 4.89 indicated that the pattern of the vowels on the chart had two discernable groups as per the dialects in EkeGusii. RM1 and RM2 are speakers of the Rogoro dialect and they seem to have their vowels (in blue and red marks respectively) close together and on the chart. The same applies to the speakers of the Maate dialect (MM3 and MM4) whose vowel points are more spread on the chart than their Rogoro counterparts.

Table 4.109: *F2-F1 results for vowels and their SDs for Rogoro dialect males*

Vowels	F2	F2SD	F1	F1SD
i	**1921**	76	**315**	7
e	**1736**	71	**358**	6
ɛ	**1587**	127	**404**	32
a	**1283**	8	**494**	19
ɔ	**1220**	35	**396**	23
o	**1198**	17	**360**	29
u	**1361**	134	**298**	39

Tab. 4.109 indicates that F1 values for /i/ and /e/ were very low showing that the two speaker's results were very close to the average. The other vowels were a bit more dispersed from the mean. The same applied to the results for F2 with only a small SD for the vowel /a/. The difference between the averages of the two Rogoro dialect speakers was not significant as p-value was greater than 0.05.

The adult males that spoke the Maate dialect were compared with those of Rogoro dialect in Tab. 4.110.

Table 4.110: *F2-F1 results for vowels and their SDs for Maate dialect males*

vowel	F2	F2 SD	F1	F1 SD
i	2327	2	293	20
e	2093	97	400	20
ɛ	1950	67	440	1
a	1572	72	595	21
ɔ	1524	129	471	12
o	1354	54	427	25
u	1527	99	310	6

The Maate speakers of Ekegusii showed less deviation from the average as witnessed by the low values of SDs as compared to the SDs on Tab. 4.110 for Rogoro dialect. Again, the Maate dialect males have a greater range for both F1 and F2 which translated to their vowels to be more dispersed on the chart as compared to those of Rogoro dialect whose vowels are very close from the highest /i/ to the lowest /a/ and front-back distinction. The results for the vowels from the speakers of the two dialects were captured in Fig. 4.90.

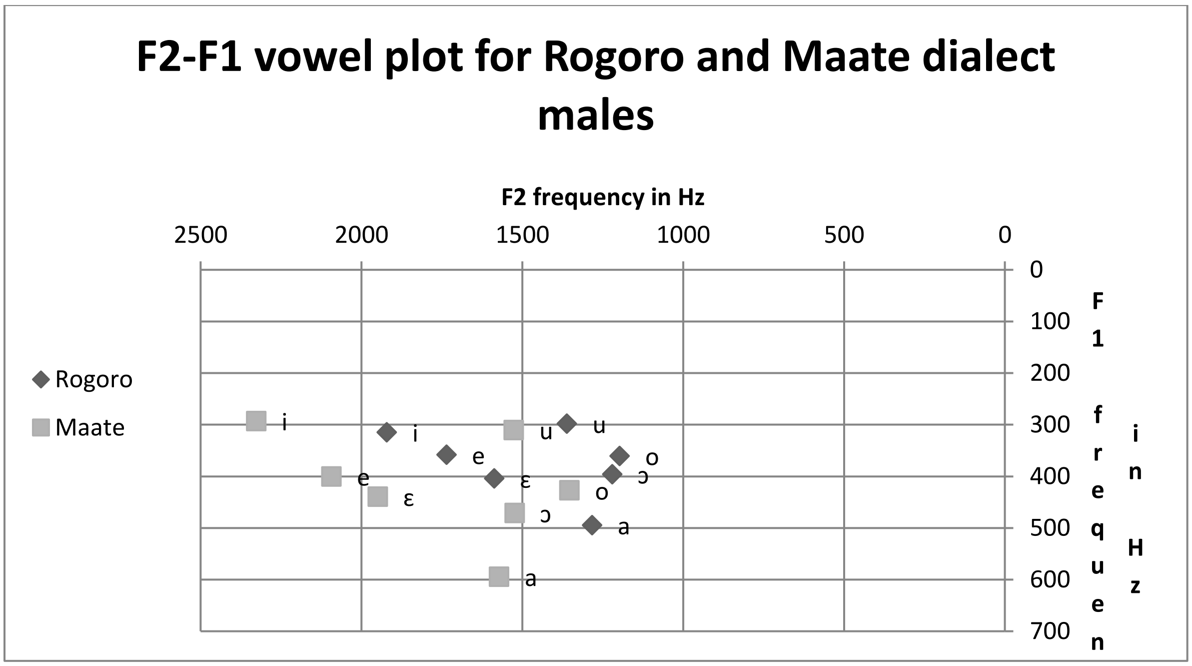


Figure 4.90: F2-F1 vowel plots for male informants of Rogoro and Maate dialects

The vowels by the Maate dialect seem to be pushed to the front than those of the Rogoro dialect that are concentrated around the centre. A significance test to measure the difference between the two dialects realised that F2 values between the two dialects were $p=0.0001$ while F1 had a significance difference of $p=0.01$. So both F2 and F1 differences were highly significant, that is, below the statistical threshold of $p<0.05$.

The result for F0 and formants for vowels in running speech are similar to those in citation form. A T-test run on them to uncover whether the differences observed were of statistical import yielded p>0.05. This means that the differences observed on the vowel data of running speech and that of isolated words in citation form (c.f 4.1.1.1) in F0 and formant values for the vowels for males were just random and not a pattern discernable in the language.

Generally, the adult females had fundamental frequency twice as much as that of the men. The formant values for the females, Tab. 4.111, showed consistently to be higher than those of the men.

Table 4.111: *F0, F1, F2 and F3 results for vowels and their SDs for females*

vowel	F0	F0 SD	F1	F1 SD	F2	F2 SD	F3	F3 SD
i	239	19	333	25	2245	158	3079	278
e	214	30	440	27	2006	130	2914	156
ɛ	192	29	496	29	1864	100	3014	256
a	209	74	632	39	1758	138	2955	288
ɔ	249	24	538	22	1453	191	2863	329
o	211	15	456	22	1291	126	2798	288
u	195	40	361	39	1391	69	2661	144

For the females, a small SD was recorded for F0 and F1 scores. This means that the four informants had averages that were not much dispersed from their general average. The vowel /i/, just like the males before had the lowest F1 and the highest F2 placing it at the highest and front most point on the chart. Extracts of F2 and F1 from Tab 4.111 were used to come up with Fig. 4.91 which plots the vowels on a chart.

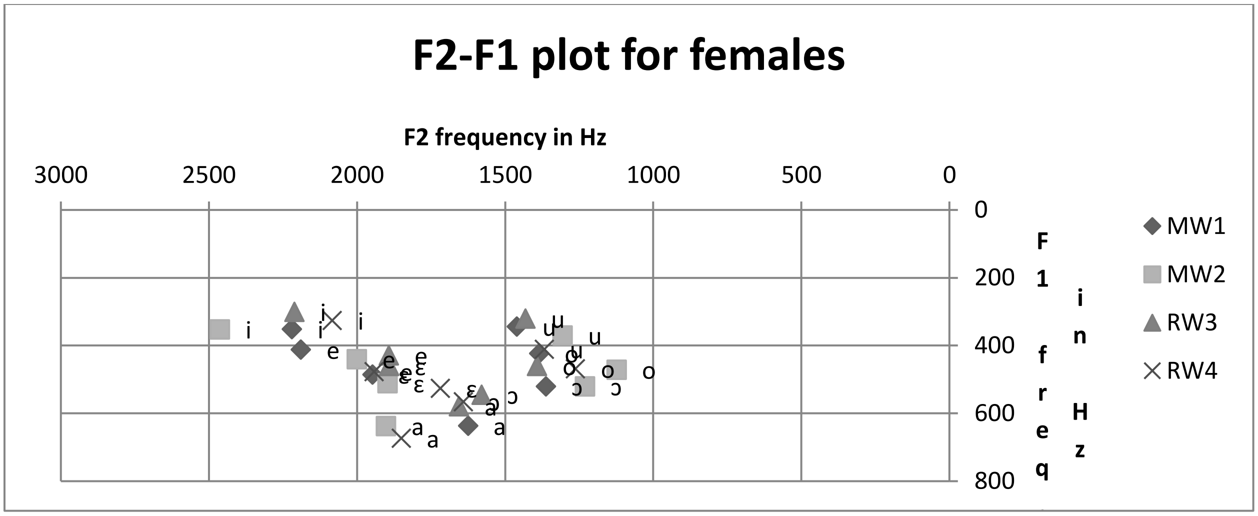


Figure 4.91: F2-F1 vowel plots for adult female informants of Rogoro and Maate dialects

Females' values seemed to be more homogeneous than for males except for obvious outliers like MW2 clear on Tab. 4.111. The females also have a clear order of the vowels just like the adult males above: /i/ is the highest and front most placed. For the front vowels, /i/ is followed by /e/ then /ɛ/ in that order. /e/ and /ɛ/ are pushed to the centre to overlap with the central vowel /a/. The back vowels /u o ɔ/ are in close proximity but in their clear order.

The females were also categorised according to dialect. MF1 and MF2 spoke the Maate dialect while RW3 and RW4 spoke the Rogoro dialect. Significance test done on them to define their differences statistically yielded a p>0.05. The meaning of that was that the females from the two dialects had no significant difference between them. This is further confirmed by the small range and SD between them.

The F0 and formant results for adult females in connected speech were compared to those got from citation data and there was no significant difference between them with p>0.05. F0 and formant results for the two sets of data were similar in all respect. The vowel chart drawn for running speech was also not significantly different.

4.3.2 Lip roundedness

For Ekegusii vowels, the distinction of lip roundedness is made between the back (rounded) and front (unrounded). This appears in the values for the second formant F2 since F2 transition correlates with place of articulation. In running speech, F2 transition is also always varying depending on the resonances from the neighbouring sounds. The vowel with lower F2 is round and those with higher F2 values are unrounded. In this respect, the Ekegusii vowels for male speakers captured on Tab 4.112 give the expected trends for the second formant (F2) which speaks directly to the gesture of lip rounding.

Table 4.112. *F2 results for vowels and their SDs for males*

F2vowel	RM1	RM2	MM3	MM4	Average	SD
i	1975	1786	2326	2329	2104	269
e	1686	1867	2162	2025	1935	205
ɛ	1497	1677	1997	1902	1768	225
a	1289	1278	1623	1521	1428	172
ɔ	1196	1245	1615	1432	1372	191
o	1186	1209	1392	1315	1276	96
u	1266	1456	1597	1456	1444	136

The results show that the back vowels have lower F2 values with /o/ having the lowest values meaning that it is most rounded for each individual male informant. This is followed by /ɔ/ and then /u/. Front vowels have high F2 values with /i/ having the highest value, that is, most spread, followed by /e/ and then /ɛ/.

The difference between the two Ekegusii dialects was also captured on Tab. 4.48 with the MM3 and MM4 for the Maate dialect having generally higher frequencies than RM1 and RM2 for the Rogoro dialect with significance measure of 0.01.

The results for the adult females for vowel F2 are captured on Tab. 4.113.

Table 4.113. *F2 results for vowels and their SDs for females*

vowels	MF1	MF2	RF3	RF4	Average	SD
i	**2220**	2463	**2211**	2084	**2245**	158
e	**2189**	2001	**1892**	1942	**2006**	130
ɛ	**1948**	1897	**1892**	1719	**1864**	100
a	**1625**	1902	**1656**	1851	**1758**	138
ɔ	**1362**	1230	**1579**	1641	**1453**	191
o	**1385**	1124	**1392**	1263	**1291**	126
u	**1460**	1306	**1431**	1368	**1391**	69

Vowel /i/ has the highest F2 frequency value which is read to mean that it had the most spread F2 values in terms of the lip gesture. This was followed by /e/, /ɛ/ and /a/. For the back vowels, /o/ has the lowest F2 value for all the informants except MF1 who has /ɔ/ with the lowest. /o/ is followed by /ɔ/ with a low F2 value and then /u/.

In terms of dialect variation, the females MF1 and MF2 representing the Maate dialect were not significantly different from RF3 and RF4 for Rogoro dialect speakers with a $p>0.05$.

4.3.3 Vowel duration

The duration of vowels is distinctive in Ekegusii. The vowel length is basically divided into two: short and long. The quantity of each vowel was measured in milliseconds. Tab. 4.114 gives a summary for the short vowels as extracted from the running speech of adult males.

Table 4.114: *short vowel durational measures in milliseconds and their SDs for males*

vowels	RM1	RM2	MM3	MM4	Average	SD
i	**81**	80	**61**	67	**72**	10
e	**80**	77	**76**	65	**75**	7
ɛ	**75**	83	**76**	75	**77**	4
a	**87**	84	**83**	78	**83**	4
ɔ	**75**	60	**76**	86	**74**	11
o	**84**	76	**74**	81	**79**	5
u	**81**	73	**68**	93	**79**	11

The short vowel form averages for all the adult male informants had a range of 11 milliseconds, from the lowest average measure of 72 milliseconds for /i/ to the longest average duration of 83 milliseconds for /a/. The SDs recorded here were relatively low, that is, between 4-11 telling that the individual scores were not much dispersed from the average but rather nearly homogeneous. There was no significant difference (p>0.05) between the duration of short vowels in citation form and those extracted from running speech.

Just like the data from the word-lists, it was noted here too that there was clear dialect motivated duration for the short vowels. Consider Tab. 4.115a and b.

Table 4.115a: S*hort vowel durational measures in milliseconds and their SDs for male speakers of the Rogoro dialect*

Short Vowel	RM1	RM2	average	SD
i	**81**	80	**81**	1
e	**80**	77	**79**	2
ɛ	**75**	83	**79**	6
a	**87**	84	**86**	2
ɔ	**75**	60	**68**	11
o	**84**	76	**80**	6
u	**81**	73	**77**	6

Table 4.115b: *Short vowel durational measures in milliseconds and their SDs for male speakers of the Rogoro dialect*

Short Vowel	MM3	MM4	Average	SD
i	**61**	67	**64**	4
e	**76**	65	**71**	8
ɛ	**76**	75	**76**	1
a	**83**	78	**81**	4
ɔ	**76**	86	**81**	7
o	**74**	81	**78**	5
u	**68**	93	**81**	18

The adult males who speak Maate dialect have vowels differing in length significantly with those of Rogoro dialect especially for the front vowels and the central vowel. Back vowels seem to be homogeneous. The significance test yielded p=0.03 to confirm that the variations observed were significant patterns in the language. For both dialects, the lengths were very similar as attested by the low SD in each dialect group. These results do not show any big variation between the duration of vowels in the citation data and the data from running speech. The short vowel average was at 80 milliseconds while that for citation data was 77 milliseconds. This can be compared to the results for females Tab. 4.116.

Table 4.116: *Short vowel durational measures in milliseconds and their SDs for females*

Short vowels	MW1	MW2	RW3	RW4	Average	SD
i	**74**	100	**64**	61	**75**	18
e	**78**	100	**85**	81	**86**	10
ɛ	**72**	75	**70**	72	**72**	2
a	**87**	87	**81**	67	**81**	9
ɔ	**83**	93	**82**	71	**82**	9
o	**86**	91	**76**	65	**80**	12
u	**80**	84	**78**	69	**78**	6

The duration of EkeGusii short vowel forms for females are comparable to those of males as the overall average length is 80 milliseconds. The front vowels and the back vowels have no significant difference with p>0.05. The small SD values attest to the fact that the vowel lengths for the females were close together and were not much dispersed from the average scores.

The sampled females were divided into two groups according to the dialects they speak. The first two, MW1 and MW2, speak the Maate dialect of Ekegusii while RW3 and RW4 speak the Rogoro dialect. The duration measures for the short vowel monophthongs had a significant difference between the females of the two dialects. The short vowels produced by the Maate dialect females were longer than those of Rogoro dialect with a significant T-test score of 0.001.

The following data gives the details for the long vowels as produced by adult males in running speech.

Table 4.117: *Long vowel durational measures in milliseconds and their SDs for males*

Long Vowel	RM1	RM2	MM3	MM4	Average	SD
i	278	264	179	190	228	50
e	252	208	175	222	214	32
ɛ	223	207	138	167	184	39
a	247	196	229	187	215	28
ɔ	182	153	136	126	149	25
o	203	222	189	185	200	17
u	247	192	168	194	200	33

The long vowels individual scores are dispersed much more from the average as compared to the short vowel forms seen earlier as evidenced by higher SDs. The long vowel averages have a range 44ms. Fig. 4.92 shows that RM1 consistently had longest duration in all the vowels except for /o/ where his scores come second.

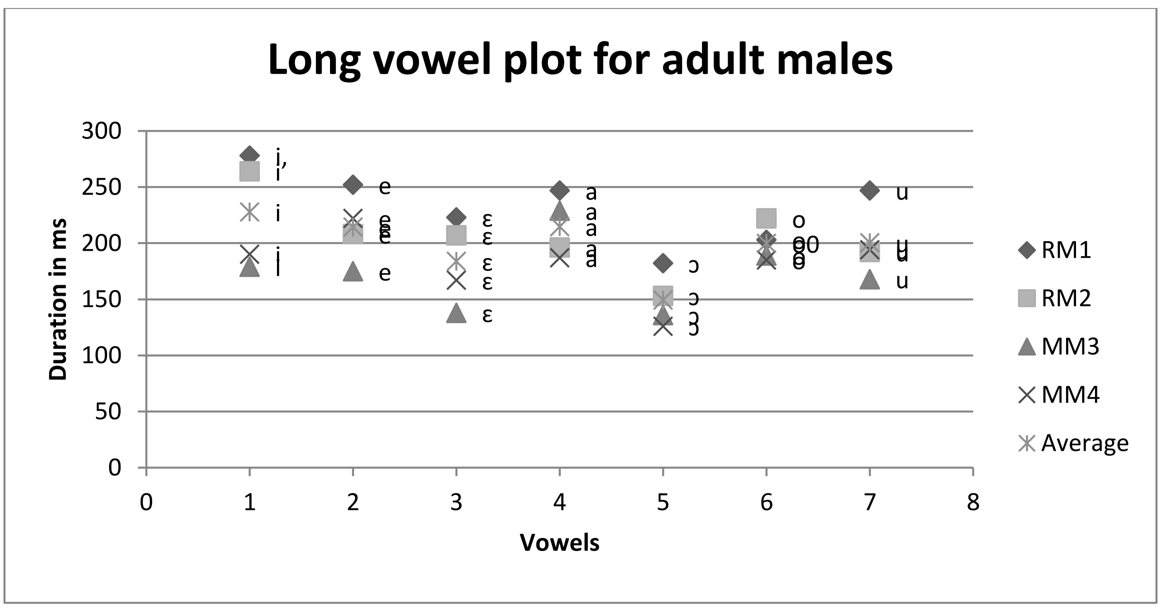


Figure 4.92: vowel duration for adult males

The front vowels and the central /i e ɛ a/ have higher values while the back /ɔ o u/ vowels have shorter spans. The arrangement of the subjects was that the first two speak the Rogoro dialect, and the last two speak the Maate dialect. The difference between these two groups was significant with p=0.0003. The significance can be visually confirmed by looking at Fig 4.38 where the RM1 and RM2 have higher values and MM3 and MM4 trail the first two speakers in length.

Tab. 4.118 gives the running speech long vowel duration measurements for the female informants for this study.

Table 4.118: *Long vowel durational measures in milliseconds and their SDs for females*

vowels	MW1	MW2	RW3	RW4	Average	SD
i	**234**	213	**282**	172	**225**	46
e	**230**	245	**247**	195	**229**	24
ɛ	**169**	167	**216**	177	**182**	23
a	**280**	280	**228**	262	**263**	25
ɔ	**166**	161	**144**	152	**156**	10
o	**196**	202	**220**	209	**207**	10
u	**161**	179	**196**	163	**175**	16

Just like the durational results for the males above, females had the front vowels with longer duration than the back vowels with a significant measure of p=0.002. Front vowel and the central vowel /a/ had individual scores more staggered as seen by the greater SD of between 23-46, while the back vowel have their SD ranging from 10-16. There were also no statistically significant differences between the lengths of the long vowels for female in running speech and those from the citation data.

4.3.4 Stop closure duration

The stop closure duration was measured from the offset of the preceding vowel to the burst of the stop which is seen as a sharp spike on the wave-form and a long vertical line on the spectrogram. This was measured for stops at the intervocalic position in the citation data but for running speech, the transition from one word to the next is just as fluid as the movement from one sound to the next in a word though for uniformity, the measurements were taken from the intervocalic position of the target word.

4.3.4.1 Stop closure Duration for /p/

The closure duration for /p/ was measured at the intervocalic position for 24 tokens in the environment of EkeGusii vowels /i a o/ representing the front most, the lowest and the backmost vowel respectively in the language. The results indicated that the closure duration for the stop consonant /p/ was shorter than the closure duration of /p/ in the citation data. The results for the male and female informants having a $p<0.05$ and between the dialects of EkeGusii had $p<0.05$. The results are as follows.

Table 4.119: *closure duration for /p/ in milliseconds and their SDs for males*

Stop/vowel	RM1	RM2	MM3	MM4	Mean	SD
Pi	31	37	22	28	30	7
Pa	30	39	20	23	28	8
Po	26	33	23	20	25	6
Mean	29	36	22	24	28	7
SD	3	3	1	4	2	1

From the result above, the closure duration for /p/ in running speech lasts from about 25 to 30 milliseconds with variations as effects of the preceding consonant. Fig. 4.39 visually displays closure duration of /p/ as varied by each of the select Ekegusii vowels and also from the average score for the group.

Being a voiceless oral stop, the airflow from the lungs is stopped at the lips and so it takes least time to stop the air and for the pressure to rise before the burst. For this reason, Ekegusii /p/ closure duration is the shortest as compared to /t/ and /k/.

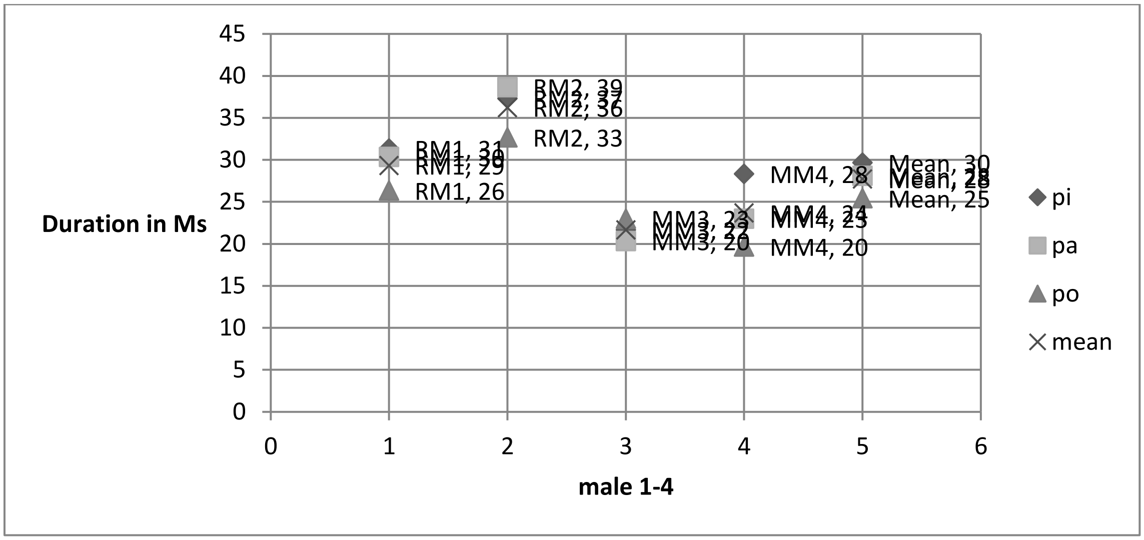


Figure 4.93: Closure duration for /p/ for adult males

These results compared with those from the citation data indicate that running speech bears less stop closure duration. The male informant RM2 recorded highest values than the others. RM2 and RM4 have greater dispersion of the closure duration from the individual mean and the group mean as evidenced by the greater SD of 3 and 4 respectively unlike RM1 and MM3 with SDs of 1 and 2 respectively.

This study also investigated the regional/dialectal differences and it noted that the Rogoro and Maate speakers had significant differences with a p=0.001. The study confirmed that the Rogoro adult male speakers had longer closure duration than their Maate counterparts. The longer closure duration is indicative of the voicelessness of the plosive according to Ladefoged (2000).

The results of the measurements for the closure duration for the stop consonant /p/ for the females are on Tab. 4.120.

Table 4.120: *closure duration for /p/ in milliseconds and their SDs for females*

Stop/vowel	MW1	MW2	RW3	RW4	Average	SD
pi	57	50	28	47	45	12
pa	49	48	31	47	44	8
po	44	42	33	56	44	10
mean	50	47	31	50	44	9
SD	6	4	2	5	1	2

Just like the males, the values for closure duration for adult females are shorter for the connected speech than for citation form with a significant difference of p=0.0003. Another statistical difference existed between the speakers of the two dialects. On Tab. 4.54, MW1 and MW2 speak the Maate dialect while RW3 and RW4 speak the Rogoro dialect. The T-test value for their difference was 0.01. This prompts the assertion that the Rogoro dialect speakers had significantly longer closure duration for /p/ than their Maate dialect counterparts as seen too for the durations extracted from words in citation form.

The results for females were corroborated with those of the males to support the view that it was a consistent pattern in the language to have longer stop closure duration for /p/ for the speakers of Rogoro dialect as compared to the speakers of the Maate dialect. This was a consistent pattern in the language.

Another thing worth mentioning is that closure duration for /p/ in the carrier phrases was far shorter than those extracted from words in citation form. The difference between the two sets of data for male informants was p=0.003 while for the female informants it was p=0.0003. The conclusion is that running speech reduces closure duration for /p/ significantly for both males and females with the degree more for females than for the males which is attributed to different sex physiology.

4.3.5.2 Stop closure duration for /t/

The stop consonant /t/ had closure duration that was longer on average than /p/ but shorter than /k/. The mean lengths for stop consonant /t/ coming after select Ekegusii vowels for the adult males were captured on Tab. 4.121.

Table 4.121: *closure duration for /t/ in milliseconds and their SDs for males*

Stop/vowel	RM1	RM2	MM3	MM4	Mean	SD
ti	**53**	20	**45**	37	**39**	14
ta	**53**	55	**40**	43	**48**	7
to	**45**	34	**32**	34	**36**	6
mean	**50**	36	**39**	38	**41**	6
SD	**5**	18	**6**	4	**6**	5

The average duration for the stop consonant /t/ was 41 milliseconds when averaging all the vowel contexts. The results on the Tab. 4.121 indicate that the stop consonant /t/ is longest when coming after /a/ with 48 milliseconds; when appearing in the environment of /i/ it averaged at 39 milliseconds and in the environment of /o/ it was 36 milliseconds.

This report was used to generate the scatterplot that visually displays the consonant quantity.

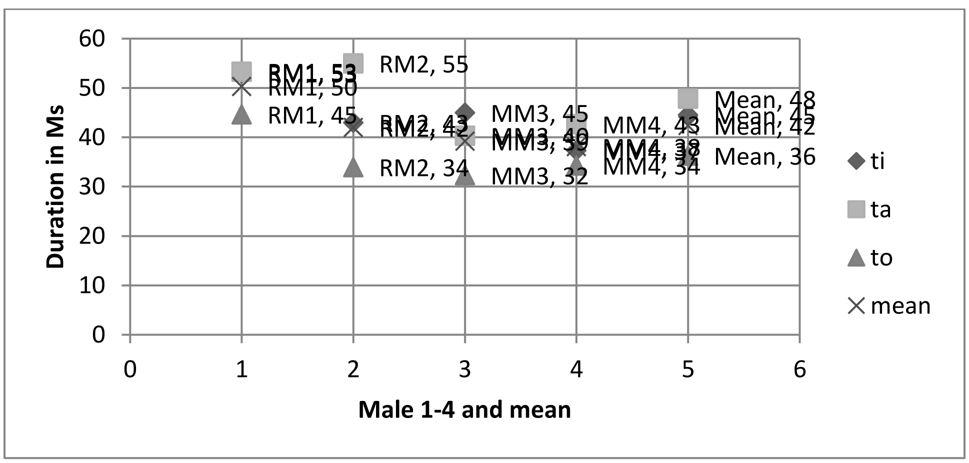


Figure 4.94*: Closure duration for /t/ for adult males*

RM2 once more had a big SD value of 18 as compared to the other adult male informants with SDs 6 and below. This explains why the values for /ti ta to/ are widely dispersed on Fig. 4.84.

The closure duration for /t/ for the other males are a bit compact, clustered around nearly the same region. The average range is 9 milliseconds though the general range for the closure duration for /t/ was 21 milliseconds.

A significance test to check out the differences between the two dialects in Ekegusii yielded a p value of 0.02 which was highly significant being below the statistical threshold of 0.05. The two dialects can be discerned from the values from /t/ and /p/ above with the Rogoro dialect speakers having longer closure duration of the stop than the Maate dialect speakers for the adult males.

The stop consonant /t/ seems to have a lesser length compared to /p/. The possible reason for that is subject to the discussion in chapter five. Compared to the closure duration of the stop in citation form, these results confirm that running speech has shorter span for the closure duration of /t/ than the data in citation form.

Tab. 4.122 gives a summary for the female subjects for this study.

Table 4.122: *closure duration for /t/ in milliseconds and their SDs for females*

Stop/vowel	MW1	MW2	RW3	RW4	Average	SD
ti	**53**	50	**44**	55	**50**	4
ta	**42**	44	**32**	35	**38**	6
to	**54**	50	**32**	35	**43**	11
mean	**50**	48	**36**	41	**44**	6
SD	**7**	3	**7**	11	**6**	3

The closure duration for the stop consonant /t/ for female informants had a small average range of 12 milliseconds. The values were not scattered as confirmed also by the small SDs for each female at the bottom of the table and averagely to the extreme right of the table.

Just like for the results of /p/ above and for males also, females who speak the Rogoro dialect had significantly longer closure durations than those who speak the Maate dialect. The p-value for the differences was at 0.03 which meant that there was a 97% chance that this was a pattern in the language and not just a random occurrence to confirm acoustically existence of dialects in Ekegusii.

4.3.5.3 Stop closure duration for /k/

The last voiceless velar stop /k/ had the following closure duration results recorded for the adult males sampled for this study.

Table 4.123: *closure duration for /k/ in milliseconds and their SDs for males*

Stop/vowel	RM1	RM2	MM3	MM4	Mean	SD
ki	38	36	30	48	38	7
ka	41	39	58	55	48	10
ko	34	33	42	46	39	6
Mean	38	36	44	49	42	6
SD	3	3	14	5	6	2

The results above when compared to those from the citation data, the point towards the trend here that the closure duration of the stop in the citation data is longer than this one got from running speech just like /p/ and /t/ above. The average duration of /k/ stop gap was 42 milliseconds long. Fig. 4.95 gives a visual display of the variations within the individual and between the informants.

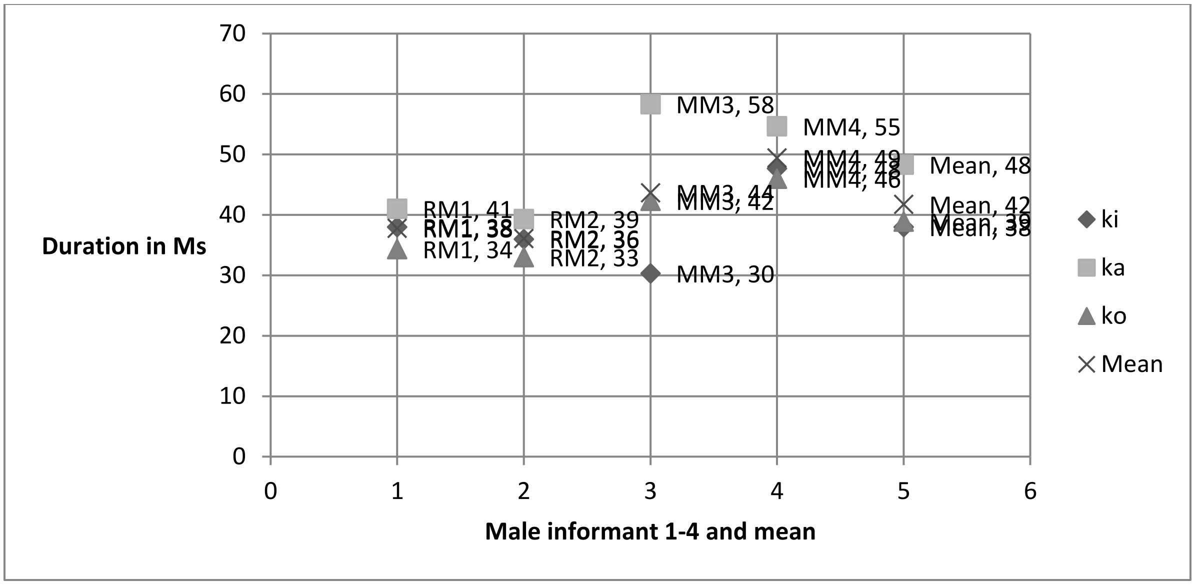


Figure 4.95: Closure duration for /k/ for adult males

The average range for/k/ was 10 milliseconds. /ka/ had higher values consistently than the measurements for /ki/ and /ko/. The low SDs indicates that the individual values are clustered close together without much dispersal. Fig. 4.95 shows that each of the vowels affected the length of the closure duration for/k/.

The difference between the Rogoro and Maate dialects were also clear from the T-test results. The two dialects were significantly different with a p= 0.02.

Tab. 4.124 displays the closure duration results for the female informants for this study. Notably, the average duration for the females in running speech is shorter than that of words in citation form discussed in section 4.2.

Table 4.124: *closure duration for /k/ in milliseconds and their SDs for females*

closure dur	MW1	MW2	RW3	RW4	Average	SD
Ki	36	39	53	37	41	8
Ka	68	52	59	70	62	8
Ko	51	50	55	67	56	8
Mean	52	47	56	58	53	5
SD	16	7	3	19	11	7

The closure duration for females had an average range of 21 milliseconds. Generally, too, the closure duration for /k/ for the females was significantly longer than that of the males with a difference p=0.02. The results showed that the values posted by the various females were not much dispersed from the average as witnessed by the small average SDs at the far right of Tab. 4.124.

The table also shows that the values for the closure duration for the two dialects differed significantly. The values for /k/ confirm the pattern so far seen for the other stop consonants for the females as well as those of males in that the speakers of Rogoro dialect had longer closure duration than those speakers of the Maate dialect with a p-value of 0.004.

4.3.5 Voice onset time

The voice onset time for all the stop consonants was measured, from the end of the vowel preceding the stop consonant to the point when the voicing of the following vowel starts. Voice onset time for voiceless stops is also equal to the voicing lag. The following are results of the VOT measurements.

4.3.5.1 Voice onset time for /p/

The results for the voice onset time for the adult males were captured in Tab. 4.119.

Table 4.119: *Closure duration for /k/ in milliseconds and their SDs for males*

VOT	RM1	RM2	MM3	MM4	Mean	SD
pi	10	15	8	8	10	3
pa	9	9	8	7	8	1
po	8	8	8	8	8	0
mean	9	11	8	8	9	1
SD	1	4	0	1	1	2

The average time the plosive takes from burst to the onset of voicing of the following vowel is a cue that is used to gauge the voiced or voiceless distinction of stop consonants and for place of articulation. The average VOT for /p/ is 9 for these four male informants. Tab 4.119 above gives the VOT for male /p/ extracted from male speakers. When compared to /p/ from word lists, the difference is not significant at p=0.09.

The values for all the four male informants were very close and this was evidenced by the very low SD values for the individual scores and between the subjects as well as range which was from 0 to 3. The scatter plot on Fig. 4.86 better shows these differences within the individual and between the informants.

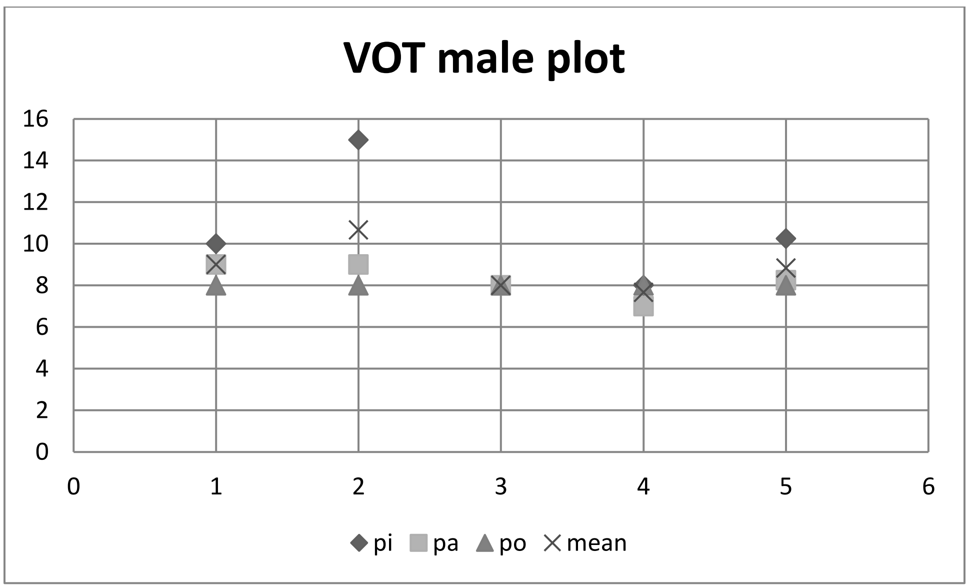


Figure 4.86: VOT for /p/ for males

Adult male 3 and 4 had VOT scores that were very close. Those for the first and second male had scores that were a bit dispersed from the group mean. MM3 and MM4 (Maate dialect) had lower VOT scores as compared with those of RM1 and RM2 (Rogoro dialect). This was confirmed with a Student's test with a value of 0.02 which means that the differences were highly significant and can be attributed to patterns in the language.

Tab. 4.120 displays the VOT results for female informants for this study.

Table 4.120: *closure duration for /p/ in milliseconds and their SDs for females*

VOT	MW1	MW2	RW3	RW4	Mean	SD
pi	7	8	11	7	8	2
pa	9	8	8	8	8	1
po	8	7	7	7	7	1
mean	8	8	9	7	8	1
SD	1	1	2	1	1	1

The VOT of the stop consonant /p/ ranged from 7 milliseconds to 8 milliseconds with a low SD ranging from 1-2. This means that values for females were indeed clustered together without any significant outliers.

When the average durations of VOT for females are compared to those of the males, for all the tokens, they yield a significant value of 0.02. This sits above the boundary of the statistical significance threshold of $p<0.05$. Simply put, the females had shorter VOT than the males by an average of 1 millisecond.

The results for the females were also analysed statistically between the speakers of the two dialects in Ekegusii. Maate and Rogoro dialect speakers were seen to have no significant difference as $p>0.05$. The only noted parity was gender influenced.

4.3.5.2 Voice onset time for /t/

The adult male informants were recorded to have the VOT duration for the stop consonant /t/ on Tab. 4.121.

Table 4.121: *VOT for /t/ in milliseconds and their SDs for males*

Adult males					Average	
VOT	**RM1**	**RM2**	**MM3**	**MM4**		**SD**
ti	38	10	27	23	25	12
ta	29	27	21	22	25	4
to	32	28	20	26	27	5
mean	33	22	23	24	25	5
Standard Deviation	5	10	4	2	1	4

The most important values here are the means since the mean normalizes the outliers. The average VOT for the adult male informants was 25 milliseconds. /ti/ had the highest SD of 12 while the other two ranged between 4 and 5. This can be visualized better in a scatter plot as in Fig. 4.87.

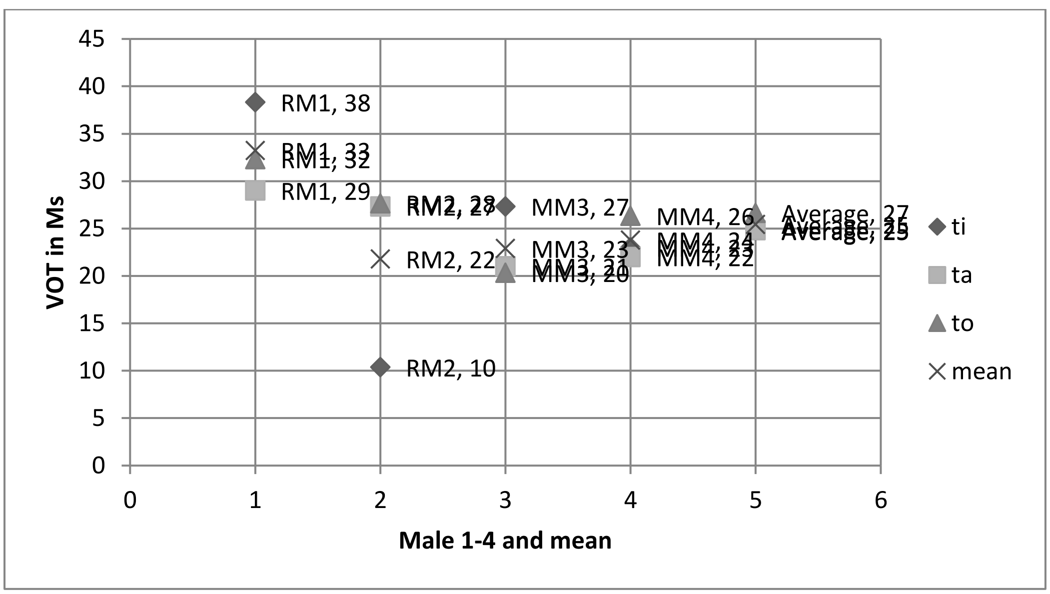


Figure 4.87: VOT for /t/ for adult males

Significance tests done indicate that the differences between the Maate and Rogoro dialects yielded significance value of 0.0058. This sustained the narrative that the two dialects were different in a pattern that exists in EkeGusii.

Tab. 4.122 gives the VOT test results for female informants.

Table 4.122: *VOT for /t/ in milliseconds and their SDs for females*

VOT	MW1	MW2	RW3	RW4	Average	SD
ti	25	23	14	14	19	6
ta	16	15	13	12	14	2
to	18	17	15	13	16	2
mean	19	18	14	13	16	3
SD	5	4	1	1	2	2

Just like the males above, the female informants had low SD values indicative of low dispersion from the mean value. Individual SD values were also low except for the first and second female who individually had larger ranges in their tokens. The average range was only 5 milliseconds. The difference between the speakers of the Maate and Rogoro dialects were also clear since the T-test value was 0.05. The speakers of the Maate dialect had longer VOT for /t/ as compared to the female speakers of the Rogoro dialect.

4.3.5.3 Voice onset time for /k/

The VOT scores for /k/ for the male adults for this study presented a different pattern unlike the foregoing stop consonants. The speakers of the Maate dialect had long VOT duration as compared to the informants that speak the Rogoro dialect. /k/ generally had the longest VOT duration.

Table 4.123: *VOT for /k/ in milliseconds and their SDs for males*

VOT	RM1	RM2	MM3	MM4	Mean	SD
ki	36	53	36	27	38	11
ka	18	37	20	22	24	9
ko	20	45	26	28	30	11
mean	25	45	27	26	31	10
SD	10	8	8	3	7	3

The velar stop /k/ had the longest VOT duration when with the vowel /i/ consistently for all the four adult male informants for this study. The average VOT is 31 milliseconds and a standard deviation of 7.

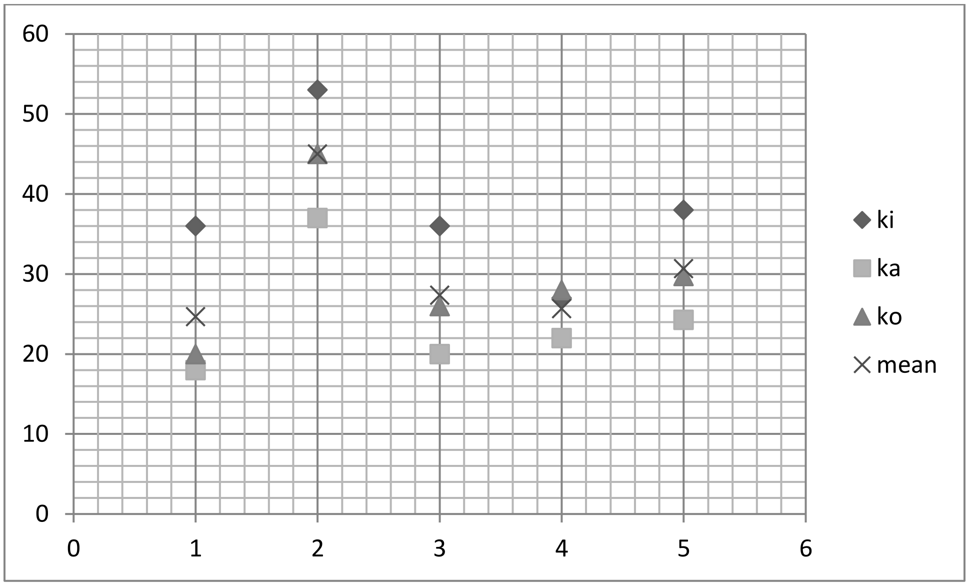


Figure 4.88: VOT for /k/ for adult males

The difference between the speakers of the two Ekegusii dialects can be discerned from Fig. 4.88. Informants MM3 and MM4 had their values higher than RM1 and RM2. The difference between the two groups (dialects) was statistically significant at 0.03.

Table 4.124: *VOT for /k/ in milliseconds and their SDs for females*

VOT	MW1	MW2	RW3	RW4	Mean	SD
ki	45	30	35	39	37	6
ka	33	23	22	22	21	5
ko	33	22	26	28	27	5
mean	37	25	23	28	29	6
SD	7	4	7	9	8	2

The stop consonant /k/ had the longest VOT for the female informants just like the males. This because of the point of obstruction at the velar and the air wave takes some time before coming out of the oral cavity. The average range for the females was 4 milliseconds.

The low SDs also indicates little dispersion from the average scores both for the individual scores and the group scores. On average, the vowel /a/ influenced the VOT of /k/ to have the lowest scores as compared to /i/ and /o/.

The Maate dialect female speakers had longer VOT span than those of Rogoro. Their difference had a high significance score of 0.03. This means that the differences are actual patterns in the language and not random chances.

4.3.6 Burst intensity of stop consonants

4.3.6.1 Burst intensity of stop consonant /p/

Burst intensity for stop consonants was measured at the point of burst after the closure duration of the stop consonant. The burst intensity values for the males and females are captured on Tab. 4.125 and Tab. 4.126. The results show that there were differences as a result of gender and also as a result of dialect. The difference between adult males and females was statistically significant with a p-value of 0.009. The dialectal difference within the two groups (adult males and females) was also significant with a p-value of 0.02.

The burst intensity for the stop consonant /p/ for words in citation form was louder than those tested for running speech. Air wave in citation form has more energy since only one word is spoken at a time as compared to the concatenation of words in connected speech.

Tab. 4.125 gives the summary for the burst intensity for the adult males for this study.

Table 4.125: *Burst intensity results for /p/ in dB and their SDs for males*

Burst intensity for males in dB	RM1	RM2	MM3	MM4	Average	SD
pi	67	73	69	72	70	3
pa	74	77	65	73	72	5
po	65	76	67	71	70	5
mean	69	75	67	72	71	4
Standard Deviation	5	2	2	1	1	1

The low SD values show that the results for the males were not dispersed widely from the average value for all the males. There was no significant difference within the group results for the three tests of /pi pa po/ as the p-value for all of them was $p>0.05$. This can also be proved by the small range of between 70-72 dB.

Tab. 4.126 gives the intensity results for the female informants for this study.

Table 4.126: *Burst intensity results for /p/ in dB and their SDs for females*

Burst intensity for females in dB	MW1	MW2	RW3	RW4	Average	SD
Pi	61	63	64	67	64	2
Pa	67	65	71	75	70	4
Po	67	65	63	72	67	4
Mean	65	65	66	71	67	3
SD	4	1	4	4	3	1

The male informants had louder bursts than the females. The average /p/ burst intensity for the males was 71 decibels (dB) while that of the females was 67 dB. There was a significant difference between the values of the females that speak the Maate dialect and those who speak the Rogoro dialect with a p-value of 0.02, where the speakers of the Rogoro dialect had louder bursts than the female speakers of the Maate dialect.

Tab. 4.127 gives the results for the burst intensity for children. It should be noticed that the results for children compared more closely with those of females.

Table 4.127: *Burst intensity results for /p/ in dB and their SDs for children*

Stop burst intensity in Db for children	MCF2	MCM1	RCM2	RCF2	Average	SD
pi	72	72	82	88	79	8
pa	74	71	84	86	79	7
po	77	76	83	86	80	5
mean	74	73	83	87	79	7
Standard Deviation	2	3	1	1	1	1

With an average range of 2 dB, the average values were too close for these informants and the small SDs tell that they were closely clustered unlike the other informants like males whose values were largely dispersed.

The difference between the scores for children and the males had a p-value at 0.017 while with the females, the p-value stood at 0.014. These mean that the intensity differences for the stop consonant /p/ was age influenced. Children had louder bursts than females and males.

4.3.6.2 Burst intensity of stop consonant /t/

The results for burst intensity for the stop consonant /t/ are captured on Tab. 4.65 for the adult males and Tab 4.128 for the adult females sampled by this study.

Table 4.128: *Burst intensity results for /t/ in dB and their SDs for males*

Burst Intensity in dB	RM1	RM2	MM3	MM4	Average	SD
ti	49	39	70	64	55	14
ta	55	60	64	62	60	4
to	57	53	73	65	62	9
mean	54	51	69	64	59	9
SD	4	11	4	2	3	4

Just like /p/ above, Tab. 4.128 for the burst intensity values for /t/ presents lower values than those for words in citation form. /ti/ has a high SD across the group while /ta/ and /to/ have small SD. Therefore, /ti/ had values scattered from the mean of 55 dB.

Considering the two dialects in EkeGusii, the T-test yielded a significant p-value of 0.015 which defines the variations to be as a result of consistent pattern in the language. The mean range for the burst intensity for /t/ was 7 dB.

Tab. 4.129 displays the results for the stop consonant /t/ for the female informants.

Table 4.129: *Burst intensity results for /t/ in dB and their SDs for females*

Burst Intensity in dB	MW1	MW2	RW3	RW4	Average	SD
ti	64	67	75	71	69	5
ta	70	72	72	78	73	4
to	71	72	71	78	73	3
mean	68	70	72	76	72	3
SD	4	3	2	4	2	1

The values for the females were very close together within the individual scores, group scores and even across the dialects. This observation is validated by the low value of SD and the low average range of only 4 dB.

The difference between the females who speak the Maate dialect and those who speak the Rogoro dialect was subjected to a Student's T-test that yielded a p-value of 0.04. Even if the score was close to the threshold of 0.05, the difference was statistically significant, suggesting that the differences were not out of random chance but a recognizable pattern in the language.

Tab. 4.130 gives a summary of the results for the stop consonant /t/ for the children informants.

Table 4.130: *Burst intensity results for /t/ in dB and their SDs for children*

Stop burst intensity in Db for children	MCF2	MCM1	RCM2	RCF2	Average	SD
ti	79	80	84	83	81	3
ta	73	73	85	86	79	7
to	74	74	76	80	76	3
mean	75	76	82	83	79	4
SD	3	4	5	3	3	1

The SD for the children informants for was equally small just like the /p/ above. The average range was 5 dB which was a confirmation of little dispersal of the values for the children with no obvious outlier. The difference between children and the males was p=0.03 and with the males it was p=0.05. The difference was significant as a pattern in the language. In all cases the children had louder bursts than the males and the females.

4.3.6.3 Burst intensity of stop consonant /k/

The values for the burst intensity for the stop consonant /k/ were captured on Tab. 4.70 for the adult males and Tab. 4.131 for the adult females.

Table 4.131: *Burst intensity results for /k/ in dB and their SDs for males*

Burst Intensity in dB	RM1	RM2	MM3	MM4	Average	SD
ki	58	55	68	66	62	6
ka	66	51	65	76	65	10
ko	66	53	67	76	65	9
Mean	63	53	67	73	64	8
SD	5	2	1	5	2	2

The values for males were not dispersed much from the average score. This is seen by low SDs of 10 and below for the individual scores and the group scores. The average range was a mere 3 decibels.

However, the Rogoro/Maate dialect divide recorded a very significant p-value difference of 0.0009. The pattern in the language is that the Maate dialect males had louder bursts by a difference of 12 decibels.

Tab. 4.132 presents the results for the burst intensity for the stop consonant /k/ for female informants.

Table 4.132: *Burst intensity results for /k/ in dB and their SDs for females*

Burst Intensity in dB	MW1	MW2	RW3	RW4	Average	SD
ki	59	58	69	72	65	7
ka	65	60	75	62	66	7
ko	56	67	73	66	66	7
Mean	60	62	73	67	65	6
SD	5	4	3	5	1	1

The results for males show an under 10 SD; it means little dispersion from the average. The difference between males and females was not statistically significant with a $p>0.05$. The difference between the dialects was statistically significant at 0.0009.

Tab. 4.133 gives the burst intensity scores for children informants for running speech. It can be seen from the table that the children had higher scores than the other two groups.

Table 4.133: *Burst intensity results for /k/ in dB and their SDs for children*

Stop burst intensity in Db for children	MCF2	MCM1	RCM2	RCF2	Average	SD
ki	78	78	87	84	82	5
ka	71	91	83	83	82	8
ko	71	69	74	82	74	6
Mean	73	79	81	83	79	4
SD	4	11	7	1	5	4

The SD for the children ranged between 4 and 8; the low SD indicated that the values for children were very close. The average range was 8 dB which support the claim that the values for children were close together with no outright outlier for this group.

The difference between the values of children and the males was not significant statistically where $p>0.05$ but it was significant when compared with the females where $p=0.015$. Children had louder bursts for the stop consonant /k/ followed by the males then the females.

In terms of dialectal variation, /k/ for running speech showed a variation between the dialects of EkeGusii. Generally, the speakers of the Rogoro dialect had louder bursts than the speakers of Maate dialect ($p=0.01$).

4.3.7 Fundamental frequency of vowels after stop consonants

Fundamental frequency (F0) is one of the cues that distinguish voiced and voiceless stops. Since EkeGusii has voiceless stops the interest will be on the F0 following stop consonant /t/ which is perceived as voiced for those speakers of the Maate dialect (assumption being that perception does not in any way influence acoustics the more reason for measuring). For this reason, we expect the F0 at the vowel onset after the stop to be higher for all the other stops except for /t/ of the Maate dialect.

4.3.7.1 Fundamental frequency (F0) after stop consonants

Consonant formants are transitory in nature since they are just ways of beginning vowels. The general trend for F0 transition at the beginning of a vowel following a stop consonant for the males did not show any statistical difference considering the three stop consonants of Ekegusii.

Tab. 4.134 gives the results for F0 of the vowels /i a o/ after the stop consonants /p t k/ for adult male speakers.

Table 4.134a: *F0 of vowel after /p/ in Hz and their SDs for males*

F0 of vowel after stop for males	RM1	RM2	MM3	MM4	Average	SD
pi	163	150	97	107	129	32
pa	124	132	104	115	119	12
po	109	118	99	105	108	8
mean	132	133	100	109	119	17
SD	28	16	4	6	11	13

Table 4.134b: *F0 of vowel after /t/ in Hz and their SDs for males*

F0 of vowel after stop for males	RM1	RM2	MM3	MM4	Average	SD
ti	153	75	141	115	121	35
ta	128	133	115	115	123	9
to	126	124	111	99	115	13
mean	136	110	122	109	119	12
SD	15	31	16	9	4	9

Table 4.134c: *F0 of vowel after /k/ in Hz and their SDs for ma*

F0 of vowel after stop for men	RM1	RM2	MM3	MM4	Average	SD
ki	131	120	111	107	117	11
ka	99	100	111	113	106	7
ko	134	106	117	109	116	13
Mean	121	109	113	110	113	6
SD	20	10	3	3	6	8

The F0 values for males had an average range of only 17 Hz for all the three stop consonants in Ekegusii. SD values were also low with the highest at 35 and the lowest at 6 meaning the dispersion from the average values was not very big for the males.

Notably, the difference between the F0 of vowel after /t/ and /p/ was 0.4 while between /p/ and /k/ was 0.2. This means that all differences were not statistically significant being far above the mathematically accepted threshold of $p<0.05$. The inference made here was that there was no indication by the results of F0 that could discriminate the stops in terms of place of articulation.

Tab. 4.135 gives the results for the adult female informants to be used to compare with the results for the males.

Table 4.135a: *F0 of vowel after /p/ in Hz and their SDs for females*

F0 of vowel after stop for females	MW1	MW2	RW3	RW4	Average	SD
pi	230	249	264	267	253	17
pa	222	251	226	218	229	15
po	231	246	236	204	229	18
mean	228	249	242	230	237	10
SD	5	2	20	33	13	2

Table 4.135b: *F0 of vowel after /t/ in Hz and their SDs for females*

F0 of vowel after stop for females	MW1	MW2	RW3	RW4	Average	SD
ti	237	218	266	214	234	24
ta	220	233	230	241	231	9
to	244	247	233	210	234	17
mean	234	233	243	222	233	9
SD	12	15	20	17	2	3

Table 4.135c: *F0 of vowel after /k/ in Hz and their SDs for females*

F0 of vowel after stop for women	MW1	MW2	RW3	RW4	Average	SD
ki	233	222	223	239	229	8
ka	234	237	220	236	232	8
ko	230	239	212	250	233	16
Mean	232	232	218	241	231	10
SD	2	9	6	7	2	3

Just like the males above, there was no significant difference between the scores of the females, either from one individual to another or even by dialect for all p-values were above the threshold ($p<0.05$). However, there was a significant difference between the scores of males and those of females with $p=0.0005$; a high significance level. This gender difference was expected since adult males and females have different structures of the vocal tract. The females had values that were nearly twice as high as those of the males. The high F0 values for the onset of vowels following the stop are indicative of the voicelessness of the stop consonants.

4.3.8 Coarticulation

The second formant transition after a stop consonant has been considered an important cue for the identification of place of articulation for plosives in CV syllables. Just like in wordlists (cf.

4.2.5), locus equation (LE) slope is steepest with /k/ followed by /p/ and then /t/ for EkeGusii stops in carrier sentences. To this extent we can just say that speech is a series of coarticulations since all the three stop consonants had slopes approximating 1.0 and a low positive or negative y-intercept value.

4.3.8.1 Results for /p/

The following values were the locus equations for /p/ for female informants.

Table 4.97: Locus equation for voiceless stop /p/ for carrier sentences of four EkeGusii female speakers

Phoneme	slope	y-intercept	r^2
P	1.08	-99	0.9881

The slope for /p/ for females was about 1.0, a very steep slope indicative of high level coarticulation between stop consonant /p/ and the following vowel for female informants. This slope was steeper than that got from words in citation form. Tab. 4.100 shows locus equation, y-intercept value and regression line for /p/.

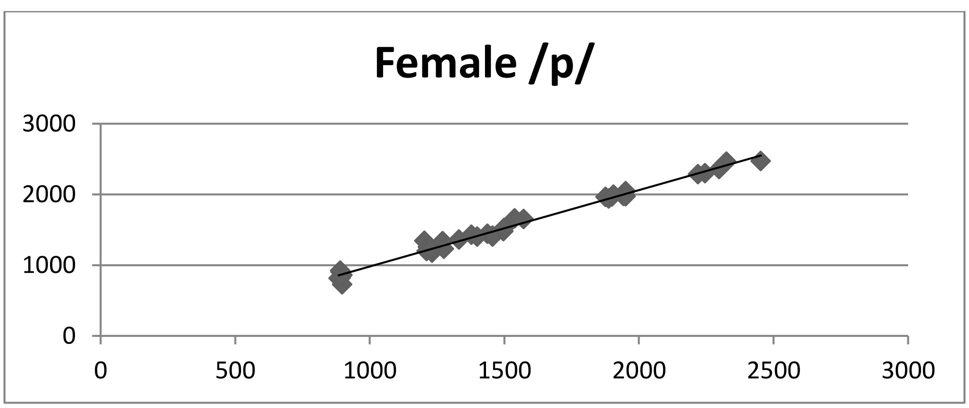
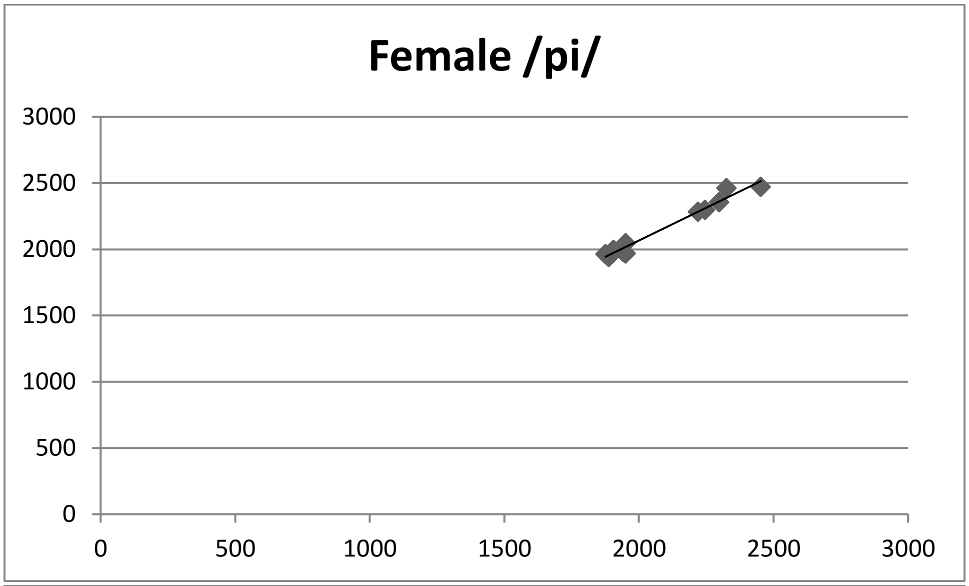
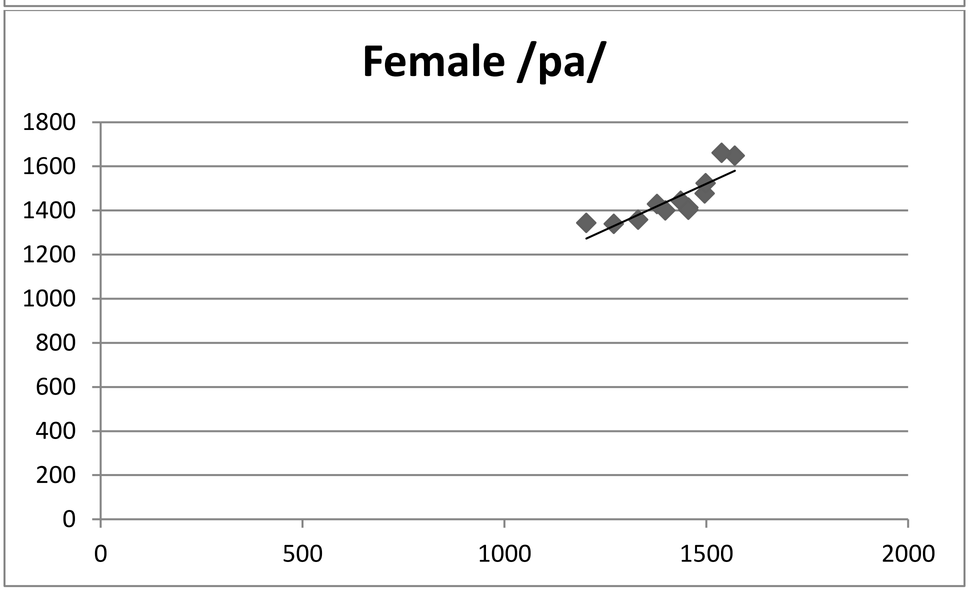


Figure 4.101 Locus equations, with plotted tokens and regression line for female subject's /p/ as extracted from carrier sentences.

The general trajectory of the regression line above can be contrasted with particular or separate results for /pi/, /pa/ and /po/ to see the effect on following vowel after stop consonant. Fig. 4.101a, b and c give the results for /p/ preceding the three select vowels.





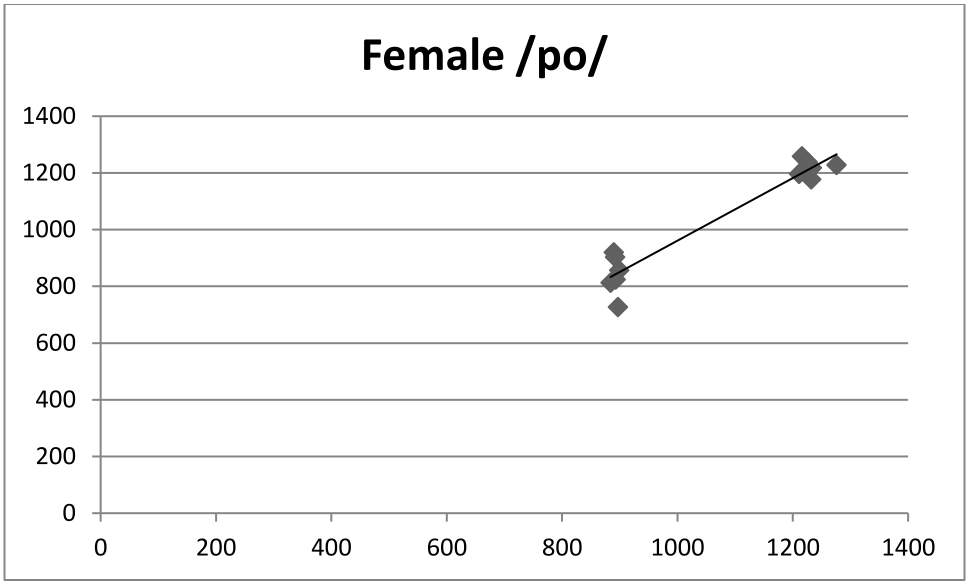


Figure 4.101a-c *Locus equations, with plotted tokens and regression line for female subject's /pi/, /pa/ and /po/ as extracted from carrier sentences.*

The slope is steepest for /p/ when it occurs in the environment for /i/ followed by /o/and it has the least steep slope occurs with /a/. This observation is confirmed when analysing y-intercept values. The higher the value the less steep the slope and the lesser the regression squared value too. Negative y-intercept value indicates that F2 onset value was consistently greater than F2 midpoint value.

As compared to the results from word lists, the difference between them was not significant with a p-value of 0.1. Carrier phrase data showed similar coarticulation correlation as compared to data extracted from words in citation form. Articulatory gestures for /p/ were similar for the two sets of data.

The results for male informants are as follows on Tab. 4.104 below.

Table 4.104: Locus equation for voiceless stop /p/ for carrier sentences of four EkeGusii male speakers

Phoneme	slope	y-intercept	r^2
P	1.025	+77.63	0.9582

The slope for male /p/ at 1.025 is similar to that of the female informants. Y-intercept value is low at positive 77 and the regression squared also is approaching 1.0. This means that the slope is very steep an indication of high levels of coarticulation between bilabial /p/ and the following vowels.

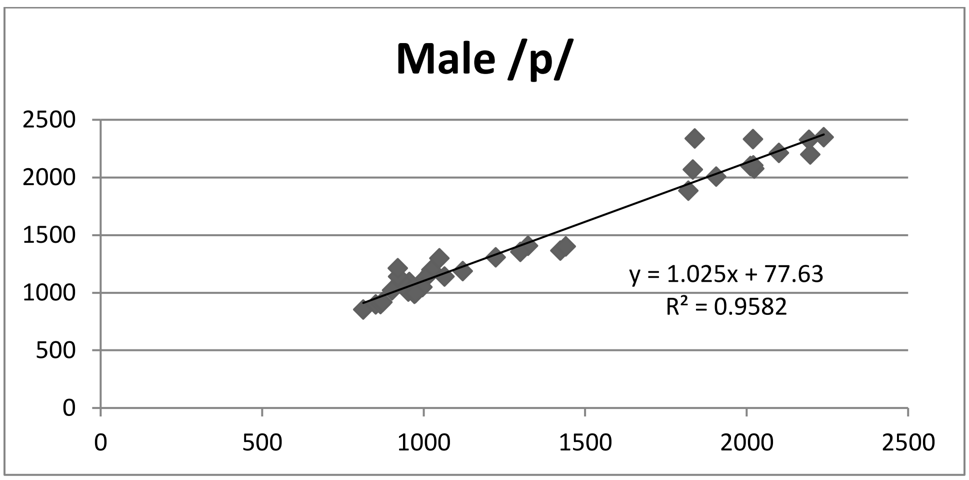


Figure 4.102 Locus equations, with plotted tokens and regression line for male subject's /p/ as extracted from carrier sentences.

4.3.8.2 Results for /t/

Let us now turn to alveolar plosive /t/. The following results were posted by the female informants.

Table 4.97: Locus equation for voiceless stop /t/ for carrier sentences of four EkeGusii female speakers

Phoneme	slope	y-intercept	r^2
p	1.174	-181	0.949

The slope for /t/ at 1.1 was generally less steep as compared to /p/. Y-intercept value was also higher on the negative meaning that F2 onsets were generally higher to F2 midpoints. Still, the slope and regression line indicated high coarticulation as attested by the plotted tokens below.

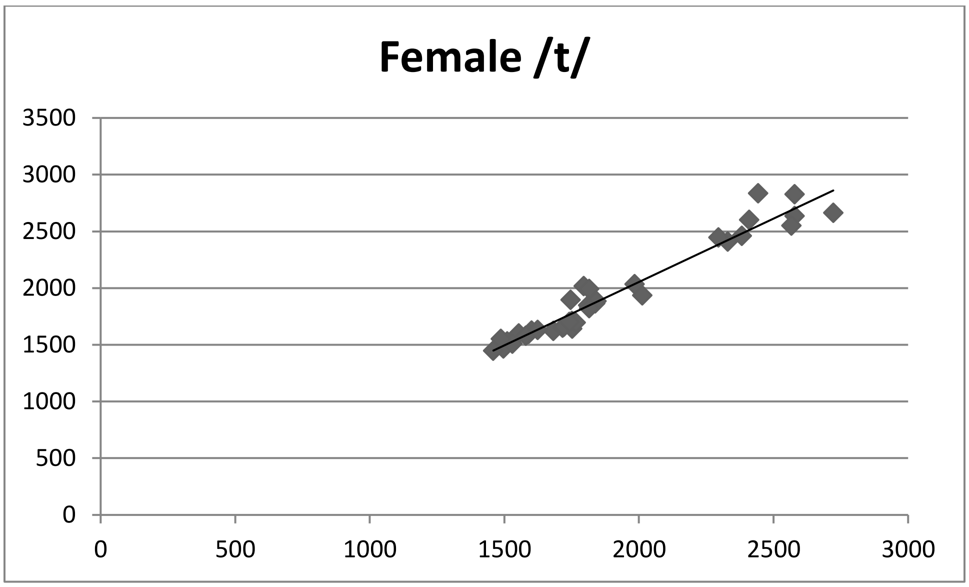
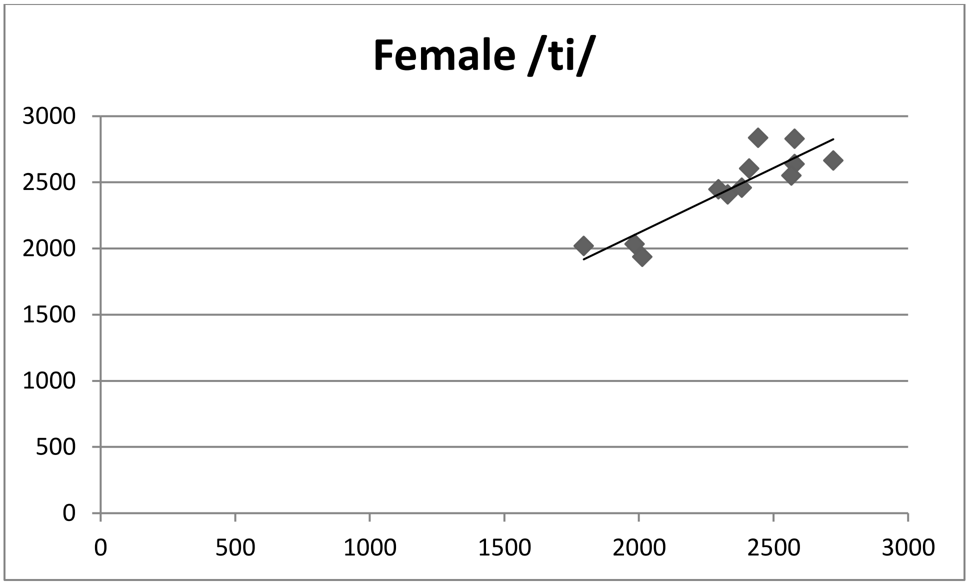
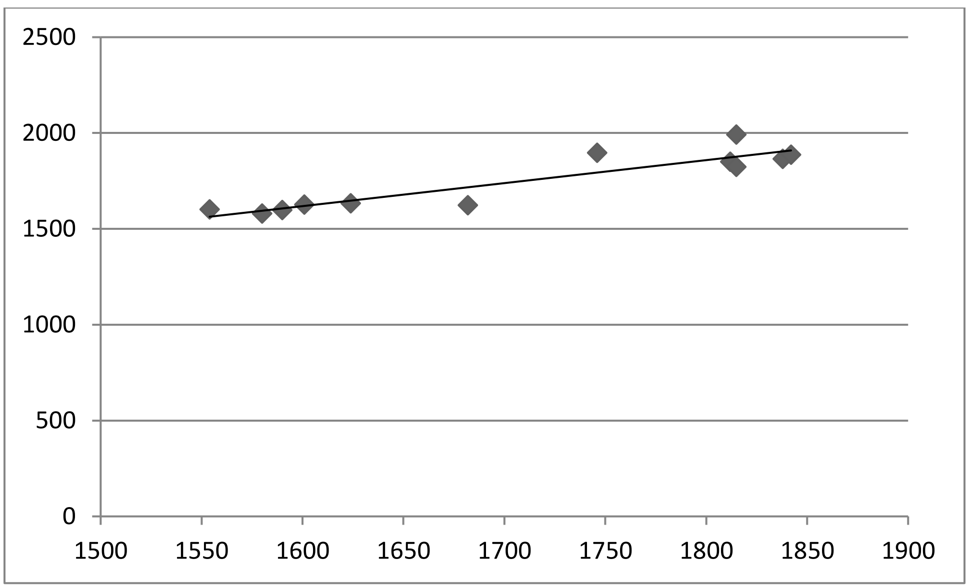


Figure 4.101 Locus equations, with plotted tokens and regression line for female subject's /p/ as extracted from carrier sentences.

When compared to the data from wordlists, there was no significant difference between the two sets of data with a p>0.05. Nonetheless, each of the three vowels had different effects to the locus equation as seen on the figures below.


Female /ti/
3000
2500
2000
1500
1000
500
0
0
500
1000
1500
2000
2500
3000


2500
2000
1500
1000
500
0
1500
1550
1600
1650
1700
1750
1800
1850
1900

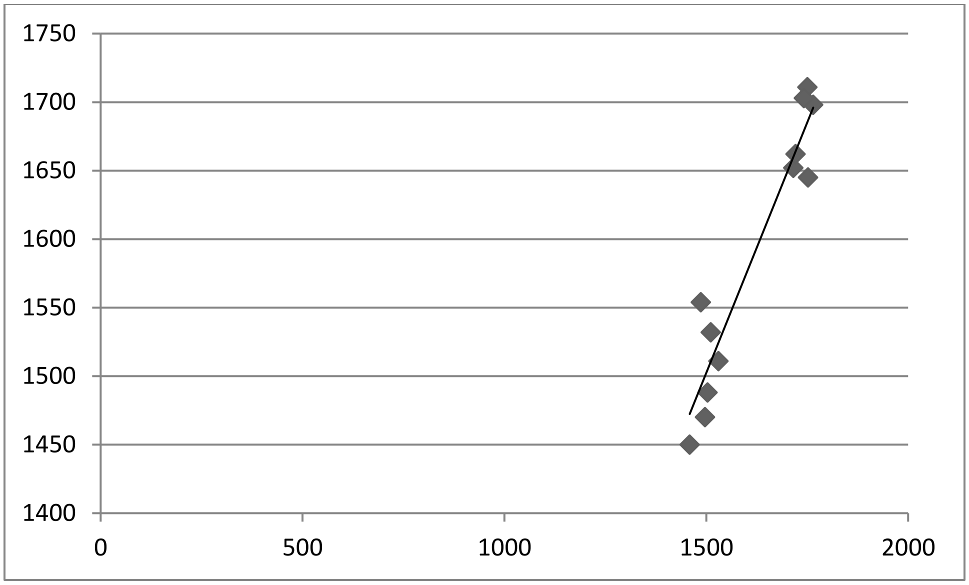


Figure 4.102a-c Locus equations, with plotted tokens and regression line for female subject's /ti/, /ta/ and /to/ as extracted from carrier sentences.

The three vowels push the regression line variously as seen on the figures. The slope is steepest with /i/ at 0.979 which is very close to 1.0. Y-intercept value is small at +160. The next in line is /a/ whose slope is above 1.2 then /o/ with a slope of 0.73. /a/ and /o/ have high y-intercept of -302 and +406 respectively, indicative of flatter slopes.

Male informants had the following results for /t/.

Table 4.105: Locus equation for voiceless stop /t/ for carrier sentences of four EkeGusii male speakers

Phoneme	slope	y-intercept	r^2
t	1.0287	-21	0.9549

The slope for /t/ for male informants was at 1.0 with a low y-intercept value of negative 21. This is a steep slope meaning greater coarticulation between /t/ and the following vowels. Locus equation and plotted tokens are on Fig. 4.106.

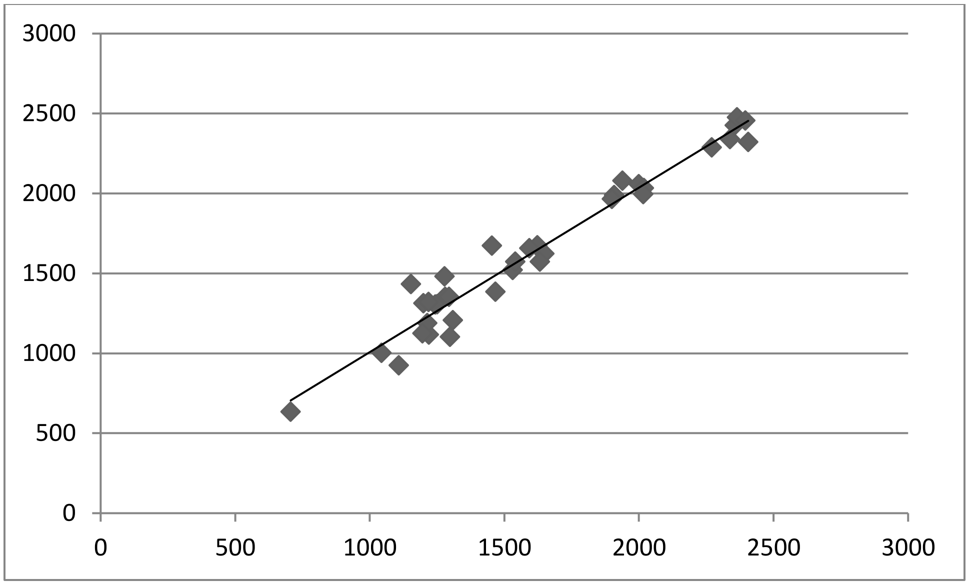


Figure 4.103: Locus equations, with plotted tokens and regression line for male subject's /t/ as extracted from carrier sentences.

As compared to citation data, carrier sentences data have indications of higher or increased coarticulation with steep slopes and lower y-intercept values. Regression squared values fluctuate depending on the following vowel after stop consonant.

4.3.8.3 Results for /k/

Having considered the locus equations and slopes for /p/ and /t/, let us now turn to the velar stop /k/. This stop had the greatest indication for coarticulation with the following vowels. Tab. 4.103 gives the results.

Table 4.103: Locus equation for voiceless stop /t/ for carrier sentences of four Ekegusii female speakers

Phoneme	slope	y-intercept	r^2
k	1.0521	-47	0.9633

When F2 onset and F2 midpoints for female tokens were plotted, the resultant slope and y-intercept values indicated very high slopes.

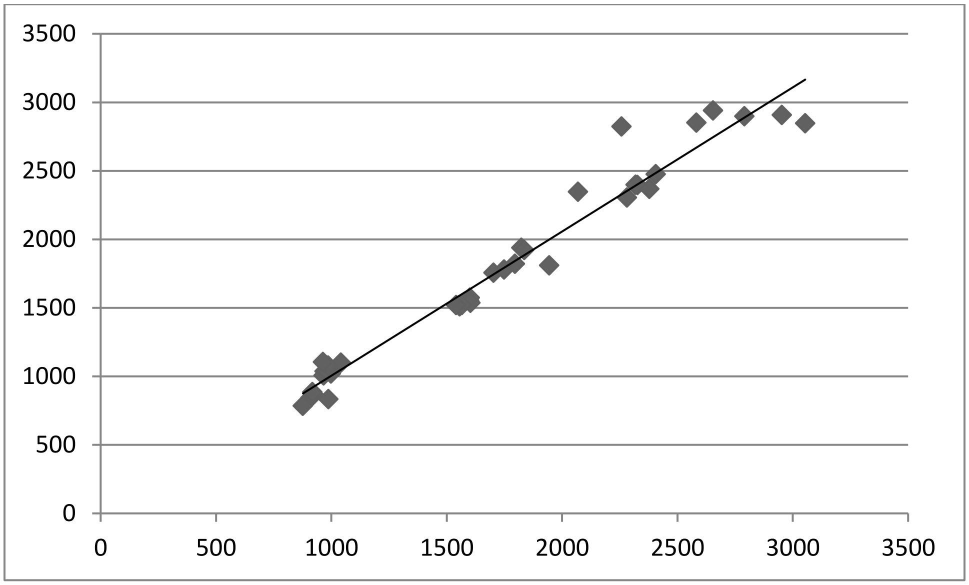


Figure 4.103b: Locus equations, with plotted tokens and regression line for female subject's /k/ as extracted from carrier sentences.

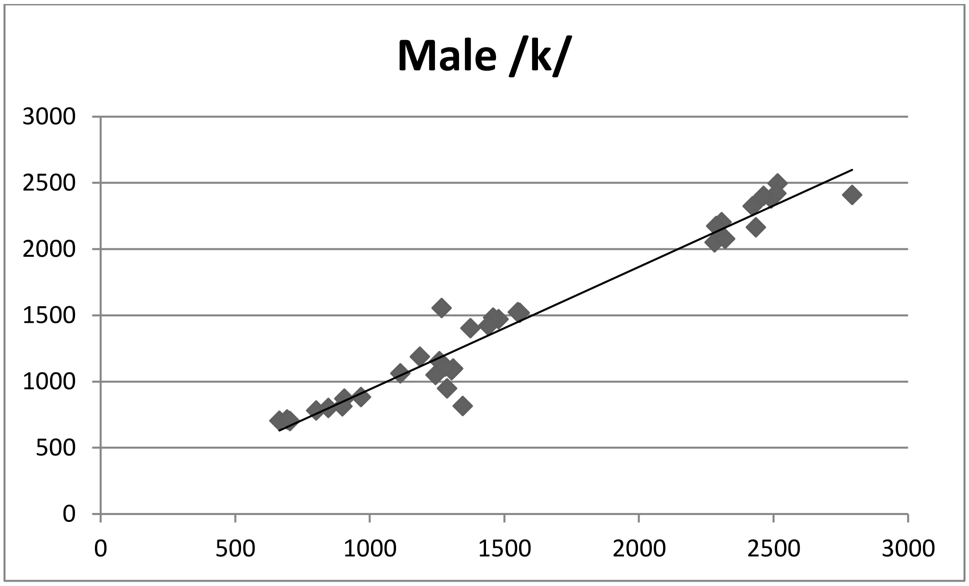
Fig. 4.103 shows that /k/ had the least figure of y-intercept indicating high levels of coarticulation between /k/ and the following vowel. The slope is also approximating 1.0. These results confirm the results also got from citation data that show /k/ as highly coarticulated with the following vowel.

The following are the results for male informants.

Table 4.104: Locus equation for voiceless stop /k/ for carrier sentences of four Ekegusii female speakers

Phoneme	slope	y-intercept	r^2
k	0.925	+15	0.9519

Velar stop /k/ also was highly coarticulated with the following vowel. The slope was close to 1.0 and a very low y-intercept of positive 15. These males had a regression squared value of 0.95. Tab. 4.104 shows the locus equation and plotted tokens for /k/



Comparing the results for the males and the females, we see locus equations and regression lines that have a similar trajectory.

CHAPTER FIVE

DISCUSSION OF RESULTS

5.0 Introduction

This chapter first presents discussion on vowels, section 5.1; discussion on stop consonants, section 5.2 and summaries on vowels and stop consonants in in running speech in section 5.3.

5.1 Discussion on vowels

Results on vowels show that Ekegusii has seven vowels appearing in four height distinctions: high, mid-high, mid-low and low. Without vowel normalization procedures on individual and group scores, there was an overlap of vowels within the vowel spaces as an indication of greater dispersion. After normalization, each vowel falls in its space with greater proximity witnessed for back vowels as opposed to front vowels. The vowels are also classified as front, central or back. This was clear when plotting the vowels on the acoustic vowel chart of Ekegusii.

Acoustic properties of the sounds of EkeGusii are depictions of Vocal tract configurations, shapes and actions, Harrington, (2011), Fant, (1960), which contribute to the acoustic signal. The unique variations are attributable to age, sex and dialect as seen in this research. In speech, the sound waves travels from source, vocal cords, through the filters, supralaryngeal vocal tract, and out into the atmosphere. The quality of the sound, in this case a vowel, is determined by the shape taken by these filters chiefly among them; tongue movement, lips, velum and jaw. What we measure as frequencies for each vowel sound are the boundaries created by the resonant chambers that manipulate the moving air particles on the way out into the atmosphere.

5.1.1 Ekegusii vowel formants

5.1.1.1 Fundamental frequency (F0) and the first formant (F1)

In this study, it was seen that F0 plays a big role in the perception of vowel height. Moving down the vowel chart of Ekegusii, /i/ for front vowels and /u/ for back vowels, F0 and F1 keep changing in opposing ways; as F0 keeps becoming lower; F1 keeps rising from the high to the low parts of the vowel chart. That is why the difference between F1-F0 is smallest with the high vowels and greatest for the low vowel /a/ in the language (Hayward, 2013). Even after vowel normalization, the F1-F0 trajectory followed this general principle.

5.1.1.2 Second formant (F2)

F2 is related closely to the position of speakers' tongue relative to the end of the vocal tract and lips, especially, how the wave that is created escapes out into the atmosphere. When the tongue is farther back in the mouth, the space at the front of the mouth is longer and so it lowers frequency (Ladefoged & Disner 2012). For EkeGusii vowel /u/, the tongue is far back in the mouth and there is a large space to the front and formants become low (1334 Hz average for Ekegusii speakers). Vowel /i/ on the opposite end leaves a small space at the front of the mouth and this is appreciated in an example given by Ladefoged (2001) when articulating /i/ and /u/ in one go; one can feel the movement of the tongue position from the front to the back. According to the source filter theory, Fant (1960, 1968), movement of the tongue helps in filtering the wave through a smaller space giving a higher frequency of F2 for /i/ and then the increased space gives rise to the lower F2 for /u/ as seen in the results for Ekegusii above.

At the same time, when the lips are rounded, the vocal tract is extended a little bit and that makes F2 value to go down. The explanation for it according to Hayward (2013) is that there is more space created for the sound wave to travel before it escapes into the atmosphere outside the oral cavity. Lip rounding makes vowels sound like they are articulated far back into the mouth. From the acoustic perspective, this could be the reason why many languages have back vowels as rounded and front vowels as unrounded. Actually in Ekegusii, the distinction between the rounded and unrounded is basically the difference between front and back vowels save only the central vowel /a/.

Vowels display an inverse relationship between space and frequency, that is, the more space the more resonant frequencies or low frequencies the sounds will have (Hayward, 2012). Wherever we are listening to people talk, we are taking note of the frequencies of sounds as we go along tracking formants. All this tracking of formants is related so much to how we modify vocal tract (the filter) as the sound wave is moving from initiator/vocal folds (the source) through the tracts and then into the atmosphere. Because of these manipulations, different parts of waves get magnified according to the properties of the space or the modification of the vocal tract they are travelling through. The vocal tract therefore acts as a filter on the wave produced by the source at the vocal folds.

5.1.2 Ekegusii vowel chart

This research quantified first and second formants of Ekegusii vowels which define vowel space. Each of the seven identified vowels was measured and results were plotted on a scatter plot for each informant, a mean for groups was derived and plotted. The study found out a similarity between Ekegusii vowels with the cardinal vowels. However, as is intrinsic for each language and dialect, Ekegusii vowel sounds differ in the location of each vowel sound owing to specific phonotactics at play in the language. The study further found out that adult males had generally low frequency values as compared to those of females who equally had lower values in comparison with the children (Paterson & Barney, 1952). Consequently, the vowels for the males were clustered together as compared to those of females and children whose vowels seem to be well dispersed all over the Ekegusii vowel chart.

Based on the evidence from the study, it is affirmed here that Ekegusii has a four-height vowel system with length distinctions as captured on Tab. 5.1. The vowels are also evenly spaced on the chart with three front vowels /i e ɛ/, three back vowels /u o ɔ/ and one low central vowel /a/.

Table 5.1: four-vowel heights of EkeGusii

	Front		**Central**		**Back**	
	Short	**Long**	**short**	**long**	**short**	**long**
High	i	i:			u	u:
Upper mid	e	e:			o	o:
Lower mid	ɛ	ɛ:			ɔ	ɔ:
Low			a	a:		

As much as this table describes the phonetic system of Ekegusii, it can as well be taken as the phonological system of Ekegusii. The distances on Tab. 5.1 are just ideal since the real vowel charts in Ekegusii (cf. Fig. 5.1) show that themed vowels are very close to each other, for both the front and back vowels. The chart also shows that /o/ is the backmost vowel in Ekegusii for adult males and females but for children, /ɔ/ is the backmost vowel sound.

Ekegusii vowel system confirms that the basic vowels in any language are /i a u/. These vowels are termed as corner vowels (Backley, 2009). For those languages with three vowels then the basic vowels suffice. For those languages with a seven vowels like Ekegusii, there are the basic vowels /i a u/ and then the other four as /ɛ ɔ e o/. Languages that have seven or more vowels have /e o/ or /ɨ ə/ where EkeGusii takes /e o/. Ekegusii further confirms the postulation that the number of height distinctions in front vowels is equal to or greater than the number in back vowels. In Ekegusii, the number of front and back vowels is equal with the same height distinctions for front vowels being mirrored by the back vowels.

The extracted spectra for the Ekegusii vowel sounds show peaks and valleys which actually reflect the decreasing and increasing amplitude of their harmonics on their up-down frequency scale. The decreasing or increasing amplitude of their harmonics reflects the various shapes taken by the vocal tract tubes as postulated in the source-filter theory that give rise to various formants. The evidence from the spectra variations is equal to the formants, the resonant frequencies of the vocal tract. In speech acoustics, the steady state of vowel formants is what the speaker aims at and is what the hearer picks. However, vowels are not produced in isolation but come in syllables with consonants depending on the syllable structure of Ekegusii. The unsteady phases (transitions) of the vowels help in identifying the consonants, while the steady phase identifies the vowels.

Albeit, only the first two formants are required to pin down a vowel on the vowel chart but they are not enough to completely capture all the qualities of a vowel sufficiently. There could be more that goes on in the perception of vowels. The evidence from the experiments here showed some overlapping of vowel sounds in their measures of F1 and F2 and yet listeners can tell apart the different vowel sounds. As the F1-F2 dimensions for each vowel are plotted, we can observe the norm and the outlier. The spacing of the vowels on the plots must be seen from what Hayward (2013) calls the 'psychologically real'. The vowels which fall in the norm and the outliers need to be explained since the listener can perceive them as alike. This gives credence to the idea that the formant peaks are the ones aimed at by the speaker as this is what the listener needs to make a phonological decision on where to place a given vowel sound given the options available in the language.

The vowel chart for children maintained the expected triangular formation though a bit different from that of the males and that of females as seen on Fig. 5.1 where all the three groups means are plotted on the same axis.

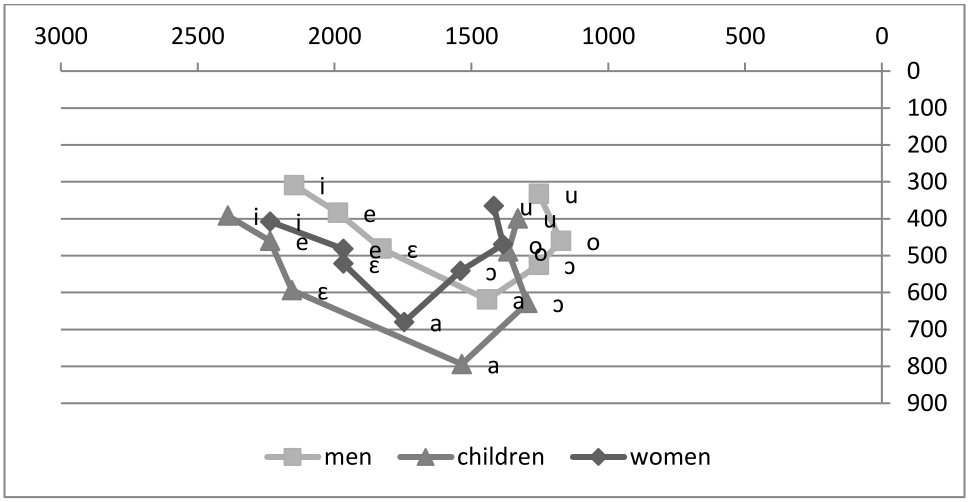


Figure 5.1: F2-F1 average for males, females and children side by side

Fig. 5.1 confirms the arrangement of the F2-F1 formants for the three groups. The children have the highest values and have the highest vowel dispersal on the chart as confirmed by higher SDs. They are followed by females and then the males with more compact and closely clustered vowels. The differences on the T-test between females and children, males and children and females and males were all significant with a $p<0.05$.

5.1.3 EkeGusii [+/-ATR] vowels

[+ATR] vowels have a lower F1 due to the perceived relatively large pharyngeal cavity. For this, EkeGusii [+ATR] vowels are located higher on the vowel space than their [-ATR] counterparts.

According to the source filter model, the longer the tube the longer the distance the sound wave travels and consequently it dumps energy all along. This places [+ATR] higher on the chart and their [-ATR] counterparts always below.

The argument that [+ATR] vowels are more centralized than their [-ATR] counterparts is not evident from the foregoing data in EkeGusii. [-ATR] vowels in Ekegusii are /ɛ/ and /ɔ/ corresponding with the /e/ and /o/ for [+ATR]. On the vowel chart for the language, the [-ATR] vowels are more drawn to the centre.

Clearly, the [+ATR] vowels that have [-ATR] counterparts are pushed more to the front, for the case of /e/, or more to the back, for the case of /ɔ/. This means that, apart from the F1 and F2 distinction, more research need to be done to tell the particular acoustic cues that relate to [+/-ATR] divide. Maybe, [+ATR] vowels sound more shallow or more constricted than their [-ATR] counterparts. In general, [-ATR] vowels have a broad and less well defined F1 peak and a smaller difference in the amplitude between F1 and F2.

5.2 Discussion on stop consonants

Results from various measurements carried out on Ekegusii stop consonants show that they differ in terms of place of articulation, gender and age. Various acoustic cues were significant in determining the differences while others were not.

5.2.1 Discussion on closure duration

Generally, females had longer stop closure duration than their male counterparts. The constriction interval or silent gap begins when the articulators contact and so stopping the air flow of the sound. The beginning of this point of closure is difficult to locate as the closure is not abrupt but progressive and even so, sometimes not complete so that there is some voicing during the gap (Hayward 2013). Fig. 5.2 shows an example of the closure duration for the stop consonants for RM2.

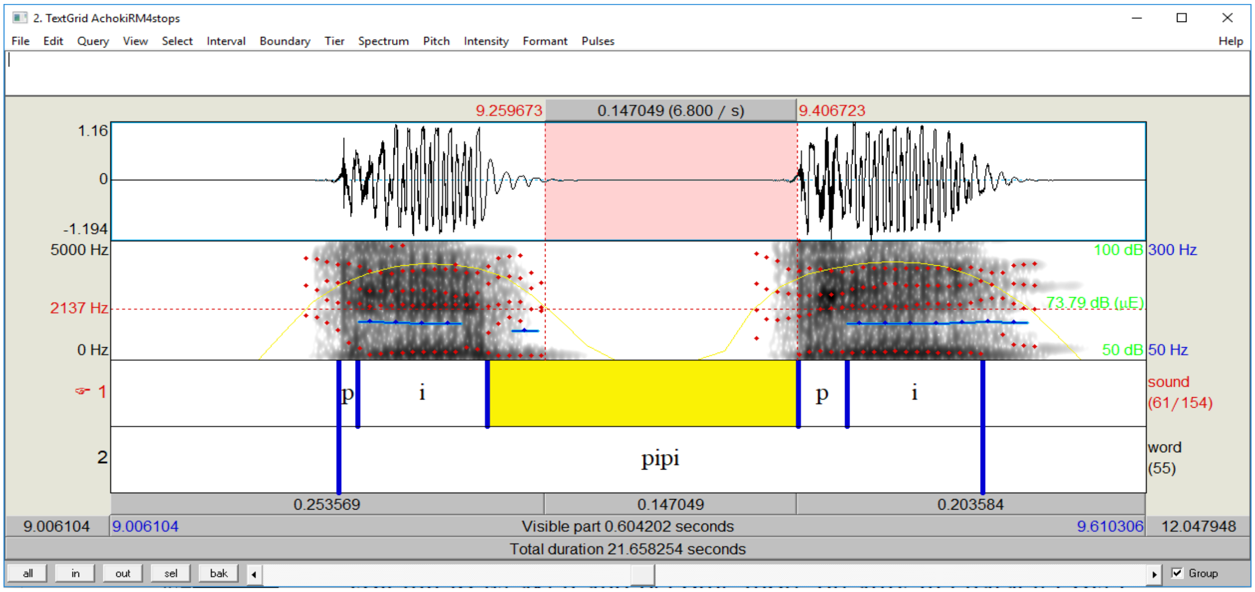


Figure 5.2a: Closure duration for /p/ in the speech of RM2

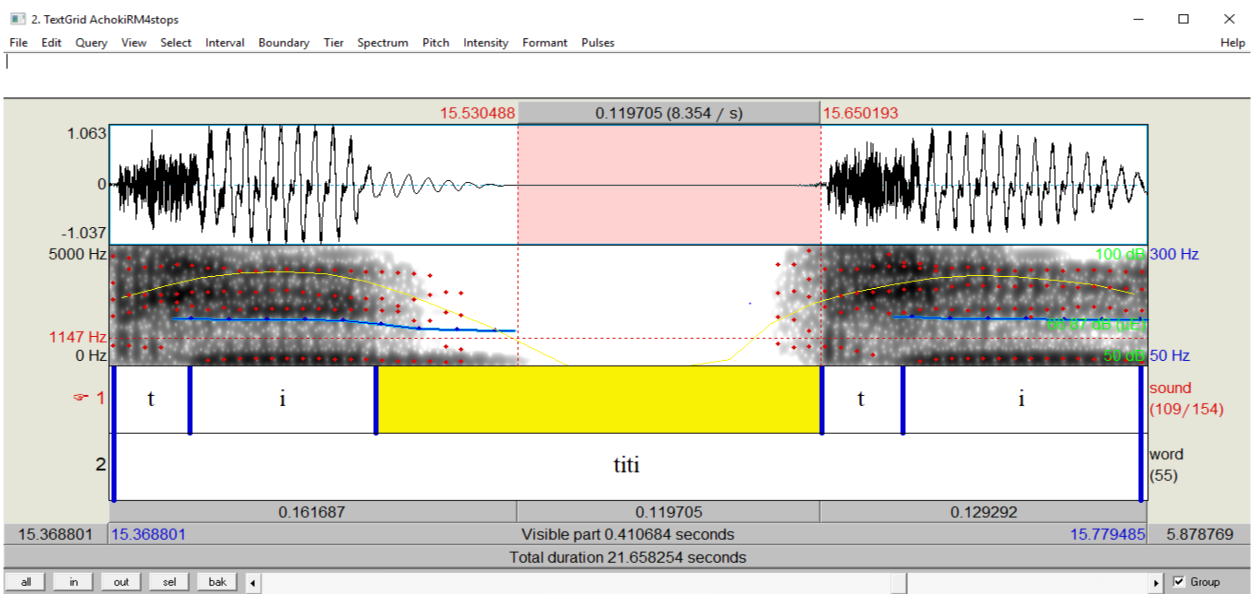


Figure 5.2b: Closure duration for /t/ in the speech of RM2

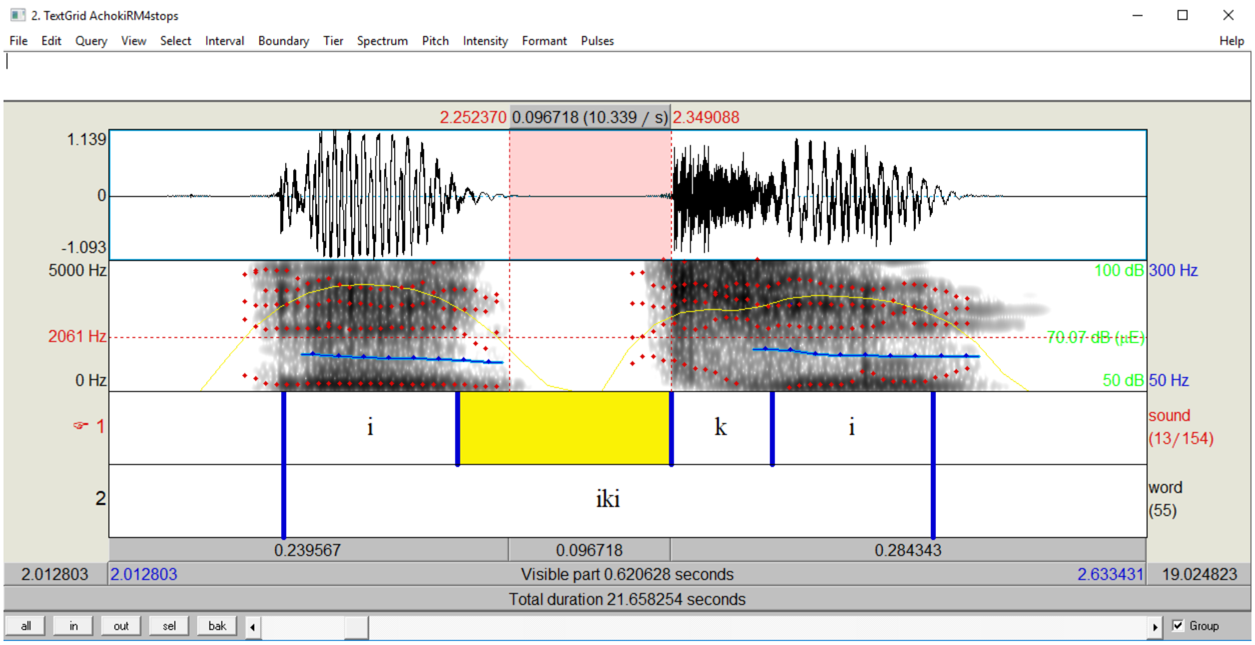


Figure 5.2c: Closure duration for /k/ in the speech of RM2

Closure interval ends with the burst, that is, release of the trapped air molecules, which is easy to locate on the waveform and spectrogram above as it corresponds with a brief vertical spike that is very clear for alveolar stops and velar stops but weak for labials. For the Ekegusii labial stop, the lips provide the filters for the air particles rushing out through the oral cavity. As per the source-filter theory, the filtering or constriction is done by the lips to produce the /p/ sound in Ekegusii. The alveolar stop /t/ finds the alveolar ridge and the tip of the tongue as the filters. Lastly, for the velar stop /k/, the velum and the back of the tongue are the filters.

The closure duration for all stop consonants in Ekegusii recorded higher duration for the sounds extracted from the wordlists as compared with the lower values for those stop consonants extracted from carrier phrases. This indicates the rapidity of running speech as articulators move from one position to another in anticipation for the next sound.

The results on closure duration show that the bilabial stop had the least closure duration then the alveolar stop followed and then velar stops had the longest closure duration. The differences were significant ($p<0.05$) indicating that the stops in Ekegusii could be discriminated by place of articulation. Females had average closure durations of all stop consonants being longer than the adult males. The difference between males and females was significant too with a $p<0.05$ on the T-test. This study can conclude that the acoustical parameter of stop closure duration is an important cue in identifying stop consonants in Ekegusii.

5.2.2 Discussion on VOT

The results from the VOT measurements in Ekegusii displayed systematic differences depending on place of articulation. There were also gender, age and regional (dialectal) variations on the scores.

Table 5.2: VOT values for the three groups, speakers of Ekegusii

VOT for children	children VOT	children SD	female VOT	female SD	male VOT	male SD
p	10	3	11	2	16	2
t	17	6	17	4	25	1
k	30	8	34	8	47	12

Adult females and children had comparable results for VOT with a p-value higher than 0.05 which makes this research to conclude that the difference between them was not statistically significant. The difference between the scores of females and males was significant $p=0.03$; the difference between males and children was also statistically significant where $p=0.04$.

The results for running speech and for the wordlists were also significant with all the three groups having $p<0.05$.

This research gives credence to the claim that Ekegusii has two dialects, EkeRogoro and EkeMaate from the foregoing results on VOT. VOT results indicated a significant difference between the two dialects for both the data from wordlists and the data from the carrier sentences.

5.2.3 Discussion on burst intensity

Since all Ekegusii stops are voiceless, the duration of VOT is also equal to the burst duration. The difference between the results for children and the males had a p-value at 0.017 while with the females, the p-value stood at 0.014. The burst intensity differences for the stop consonant /p/ were age influenced. Children had louder bursts than females and males.

The general trend ensued here too that, the burst intensity for the stops was louder in citation form as compared to the data got from running speech. The difference between the burst intensity was significant at $p<0.001$ between the two arrays of data.

Burst intensity cue could not discriminate between the genders as the p-value was not significant ($p>0.05$). It could not also discriminate between the ages as the children compared to adult males and adult females yielded a $p>0.05$. The most discriminated variability was dialectal. The speakers of Rogoro dialect for the three groups consistently had louder bursts than their counterparts of Maate dialect. The difference between the dialects, considering the informants for each group was $p<0.05$.

5.2.4 Discussion on Fundamental frequency of vowel after stop consonants

Fundamental frequency (F0) of vowels after the three stop consonants of Ekegusii /p t k/ could discriminate between genders and age where females had significantly higher values of up to thrice to those of the males; children too had higher F0 values to those of the females and even a bigger parity with the males. The difference is as expected from the literatures since the vocal tracts for the three groups is structured differently with adult males having longer and thicker passages compared to adult females who in turn are different from the children.

This study found out that there was no significance on the values of the three stop consonants in Ekegusii in terms of their places of articulation within each group of informants. All the comparisons within the group yielded a larger than 0.05 that is the statistical threshold. When comparing the results for the three groups, we find that the difference between the adult male and adult females was highly significant at 0.0005; the results show the difference between adult males and children was 0.0002 and the significance value for the results of children and adult females was 0.004.

5.2. Discussion on coarticulation

Coarticulation between stop consonant and following vowel can be seen in F2 transitions of vowel. This was measured for F2 at vowel onset and F2 at midpoint (Agwuele, Sussman & Lindblom 2009). The more the values of onset and midpoint are similar, the higher the rate of coarticulation between them. If the values have a high disparity, then they are said to be less coarticulated.

Ekegusii stop consonants and following vowels were seen to be highly coarticulated as the slope was steep overly at 1.0. The y-intercept value was also low either negatively or positively. Negative y-intercept values meant that F2 onset values were higher than F2 midpoint values (Everett, 2008). Fig. 5.3 and Fig. 5.4 displays combined graph for the three stop consonants and their regression lines for the female and male informants.

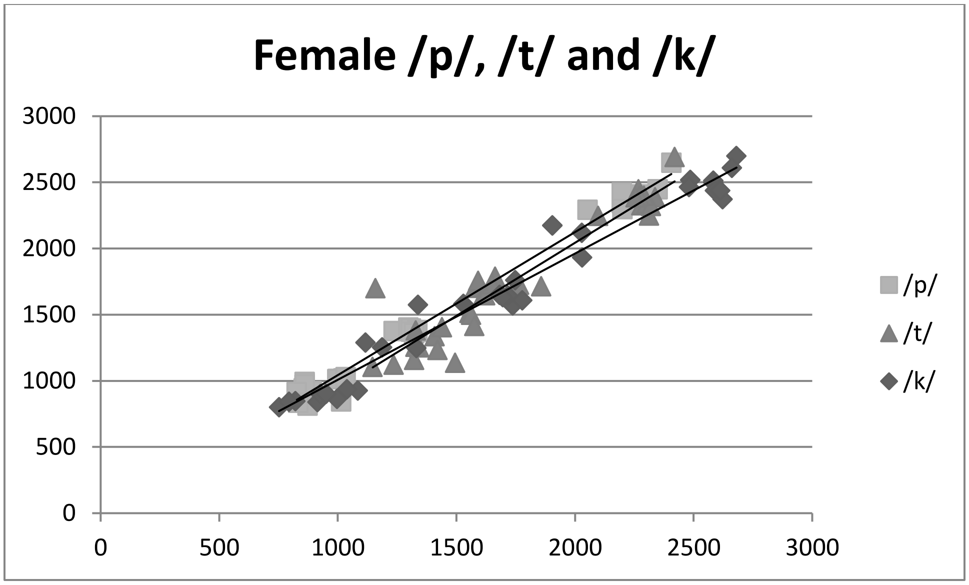


Figure 5.3: Graphic summary of locus equations and regression lines for female subject's /p/, /t/ and /k/.

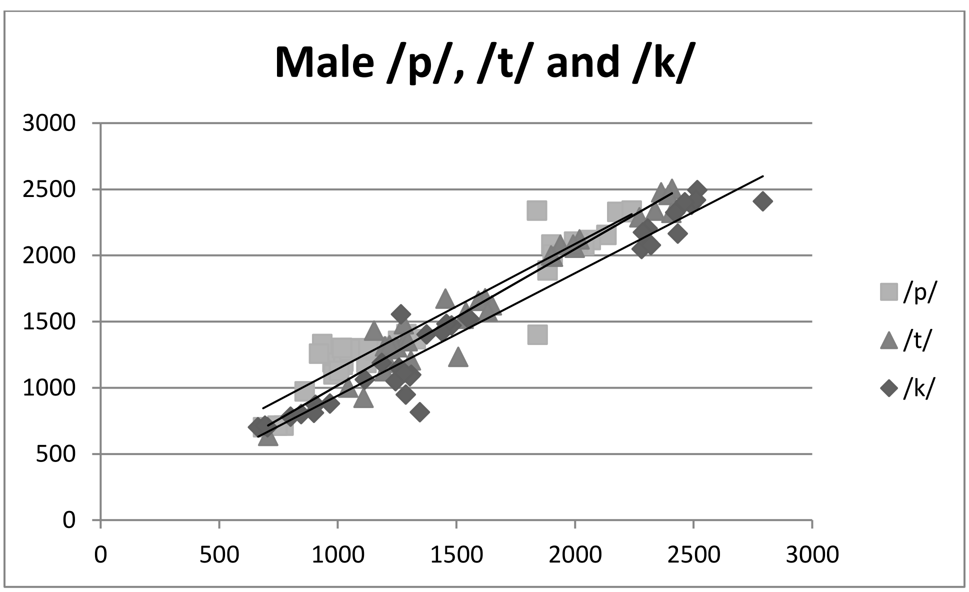


Figure 5.4: Graphic summary of locus equations and regression lines for male subject's /p/, /t/ and /k/.

Female informants had the steepest slope with alveolars /t/ at 1.1 followed by that of bilabials /p/ at 1.0 and the least steep slope for velars /k/ at 0.95. On their part, male informants had the steepest slope with alveolar /t/ at 1.03 followed by bilabials /p/ at 0.944 and the least slope was recorded for the velars /k/ at 0.925. It should be noted that all the slopes were close to 1.0 indicative of high coarticulation for all the Ekegusii stop consonants for both word lists and carrier sentences.

Despite the subtle differences noted earlier between the values for males and females, the slopes and regression lines reported for both of them are quite similar. Inter-speaker differences can be investigated further to reveal deeper patterns of coarticulation for Ekegusii stop consonants. However, locus equations for all the female and male informants reveal uniquely similar patterns of Ekegusii CV coarticulation. When we contrast Fig. 5.3 and Fig. 5.4, graphic acoustic evidence emerges of the patterns that correlate articulation of consonant-vowel interaction in Ekegusii. The isomorphism witnessed attests the patterns that are Ekegusii specific.

To the best of my knowledge, no similar locus equation plots and regression lines exist in the literatures on Ekegusii, which is a phonetically under-described language, or even for other Bantu languages related to Ekegusii. It is hoped that future phonetic studies will allow the comparison of these locus equation data with others. For the sake of this study, we can only observe the patterns of coarticulation as brought out by the locus equations of Ekegusii stop consonants.

In Ekegusii, LE can be used to mark phonetic place of articulation for stop consonants. They are also a numerical index of degree of coarticulation between a vowel and preceding stop consonant in CV sequence. Since Ekegusii syllable is basically CV, I observed here that LE had articulatory basis and that their slope and y-intercepts properties were place dependent. To this extent, there are obvious linear relationships between F2 at vowel onset relative to vowel midpoint.

CHAPTER SIX

SUMMARY, CONCLUSION AND FUTURE DIRECTIONS

6.0 Introduction

This chapter first presents summary of thesis in section 6.1; conclusion of study based on the observations and analysis of findings in section 6.2 and future research directions that can be done after this study in section 6.3.

6.1 Summary

In chapter one, a background of the study is presented. It was observed from the literatures that EkeGusii sound system still remains understudied. It is stated here that EkeGusii has two distinct dialects of EkeMaate and EkeRogoro (Bosire, 1993). EkeRogoro is taken as the standard variety because it is spoken by a vast majority of speakers apart from being used in the media, religion and school.

The gap that this study intended to fill was to bring into view acoustic analyses of Ekegusii sounds which differ from impressionistic descriptions of the sound system of EkeGusii language. In fact, there is no phonetic study done on EkeGusii language at all. Acoustic analyses give language description a firm scientific footing that is more reliable and verifiable than impressionistic descriptions. Again, through this study, the vowel chart for EkeGusii was drawn using F2 x F1 intersection points for each talker and for each group. This also helped build a case for asserting that there are fourteen vowels in EkeGusii language and not just seven as proposed by Whiteley (1965) Cammenga (2002) and Mecha (2006). This study described the qualities of vowels and stop consonants of the language.

A purposively selected sample of twelve was used to elicit target vowels and stop consonants for analysis. This composed of 4 males, 4 females and 4 children; the numbers were well above the minimum number of sample size of 3 males and 3 females for this kind of study as per Ladefoged and Disner (2012). Of these half of them for each group spoke either of the two dialects of EkeGusii.

Chapter two reviewed existing literature on acoustic phonetics in general and those on EkeGusii sound system in particular. It was noted that few literatures exist on Ekegusii sounds and none at all on the phonetics of the language. The few that are available describe EkeGusii sounds impressionistically. This was the gap in the literatures and this study intended, therefore, to fill this gap by providing acoustic descriptions of vowels and stops of EkeGusii since acoustic phonetics are evidence based and give the study of sounds a firm scientific footing unlike previous impressionistic descriptions.

A theory of acoustics - the Source-Filter Theory of speech production (Fant, 1960) – was also presented and discussed for its suitability analyzing of the sounds of EkeGusii. The basic tenets of the theory pertain to a sound wave being initiated at the ‘source’, that is, the vocal cords. This sound wave then travels from source out into the atmosphere through the vocal tubes or supralaryngeal vocal tract. The tubes are manipulated variously to produce unique quality for each sound as we know it. This manipulation by the tongue, lips, velum, nasal cavity, teeth, and jaw is what filtering entails. These filters create various projections of the sound quality that are realized and measured instrumentally as frequency. The frequencies are the acoustic qualities of the sounds that are measured, analyzed and described in this study.

Chapter three presents the methodological designs the study adopted. It presents the study site of Kisii and Nyamira Counties of Kenya, language of study, population, and sampling procedures.

It describes the data elicitation procedures, stimuli, and recording where informants were requested to come to the language laboratory on campus for the exercise. Though the lab is not attenuated, background sounds are controlled to a large extent. The informants were asked to read from a word list and carrier sentences carefully crafted to elicit target sounds into a microphone attached to a computer sampled at 44100 Hz running on Praat software. The recordings were saved into a hard-disk and copied to an external drive as a back-up. The recordings were annotated and segmented for analysis. The data thus generated had both quantitative and qualitative value which necessitated a mixed approach in data analysis.

In chapter four, the data collected for the seven vowels and three stop consonants is presented and analyzed. Seven monophthongs identified /a e ɛ a ɔ o u/ were analyzed for their fundamental frequency (F0) Formant one, two and three (F1, F2, F3). F0 pertains to pitch, F1 describes vowel height, F2 pertains to backness and vowel roundedness as well as F3. Using these results, EkeGusii vowel chart was plotted using F2 x F1. Vowel charts for adult males, adult females and children were plotted and compared. It was found out that adult males had generally low frequencies which were statistically significant followed by those of adult females and lastly for children who had highest values.

Vowel charts were further analyzed using NORM after Kendall and Thomas (2009) using Lobanov (1971) algorithm which deviates from using Hertz values for Bark values which display in better perspective of spatial distribution of vowels in the acoustic vowel space. Further, this study established that the vowels of EkeGusii took a four height distinction of high /i u/, mid-high /e o/, mid-low /ɛ ɔ/, and low /a/; three spatial distinctions of front, central and back distributed evenly with three front vowels /i e ɛ/, three back vowels /ɔ o u/ and one central vowel /a/. This phonetic vowel system can as well be taken as phonological system of the language.

This study measured vowel length or quantity. EkeGusii vowels were found out to be both long and short. Since length was found to be distinctive in the language, this research concluded that the language has fourteen distinctive vowels, that is, for every short vowel there is a corresponding long vowel.

Stop consonants were analyzed for the following qualities: closure duration, voice onset time (VOT), burst intensity, burst duration, and locus equations as markers of coarticulation. Results on closure duration indicated that the bilabial stop /p/ had the least closure duration for all the three groups of informants. It was followed by /t/ and /k/ had the longest closure duration. The differences were significant with $p<0.05$. Based on these results, it was concluded that EkeGusii could be discriminated by place of articulation.

Voice onset time results showed systematic differences according to place of articulation, gender, age and dialect. This was translated to mean that VOT could be used to discriminate EkeGusii stop consonants in terms of dialect, age, gender and place of articulation with all having statistically significant p-value of less than 0.05.

Also, results for burst intensity indicated that /p/ had louder burst followed by /t/ and lastly /k/. In contrast, children did not have significantly louder bursts than adults as expected. It was ruled out in this study that burst intensity could not discriminate stop consonants in terms of gender and age. Only that Rogoro dialect speakers had significantly louder bursts than their Maate dialect speakers ($p<0.05$).

Another measurement taken for stop consonants was that of coarticulation, that is, F2 transitions. This was measured at F2 onset and F2 mid-point. EkeGusii stop consonants were highly coarticulated as confirmed by the steep slopes for /p t k/ and low y-intercept values. LE can be used in EkeGusii to mark place of articulation for stop consonants.

Lastly, results for word-lists for all attributes above were compared to those of running speech or carrier sentences. It was noted that carrier phrases had significant lessened duration measures due to rapidity of connected speech as compared to words in citation form.

6.2 Conclusion

In this study, I set out to answer three fundamental questions on Ekegusii phonetics: 1) What are the acoustic properties of Ekegusii vowels; 2) what are the acoustic properties of Ekegusii stop consonants, and 3) How are the properties obtained from citation data are affected by running speech? To answer these questions, this study was the first one that attempts to give a complete acoustic description of Ekegusii vowels and stop consonants. This fact and data driven process is one of the ways of documenting and revitalizing a language that is faced with the challenge of being side-lined by competing languages, especially Kiswahili and English, in modern times.

Concerning the properties of Ekegusii vowels, it was noted that Ekegusii orthography has five vowels while speech data reveals that the vowels are seven. The number is supported by the literatures reviewed. As expected, there were variations among the three groups of informants, adult males, adult females and children. Children had higher values than adults and adult females had higher values than adult males. This difference was attributed to the physiological differences that exist in the vocal apparatus of different sexes and ages.

Vowel values for F0, F1, F2 and F3 were computed for individual informants by gender and age. Children consistently had higher formant values to adult females and adult males in that order owing to their anatomical differences that were statistically significant. Based on the results, this study has drawn proposed vowel charts for Ekegusii adult males, adult females and children using F1 and F2 formant values for each group.

F1 and F2 values alone can discriminate between Ekegusii vowels. They had significant contribution to the difference in variance where $p < 0.0001$ for Wilk's Lambda. 78.6% of the original grouped cases were correctly classified by F1 and F2 while 70.2% of cross validated grouped cases were correctly classified. The classification rate for Ekegusii was higher than that reported by Hillenbrand et al. (1995).

Classification of each vowel presented variations in their results depending on sex and age. Front vowels had higher classification rates for females and children while back vowels had higher classification for male informants. Female /ɛ/ had the highest correct classification while male /u/ had the lowest correct classification.

Another quality of vowels under consideration was duration. Ekegusii seemed to adopt a seven vowel system with length distinction where each short vowel has a corresponding long vowel. Duration was seen to discriminate the vowels of the three groups who were subjects to this study. Just like the results for formants, children had longest duration for both the ones classed as short vowels and the long vowels. Adult females compared closely to the children values since the difference between them was not significant with $p>0.05$. Adult males had the least vowel duration. The differences were significant with a $p<0.05$. For short vowels, /ɔ/ had the longest duration for all the three groups of informants.

Concerning stop consonants, this study found out that Ekegusii stops can be discriminated by place of articulation by the following cues: stop closure duration, voice onset time, and burst intensity, fundamental frequency of vowel after the stop consonant and locus equation and regression lines. Stop occlusion was longest for the voiceless velar stop /k/ followed by /t/ and the least stop closure duration was for /p/. The same order applied to stop VOT duration with significant differences in between. There was no significant discrimination for place of articulation from the results for F0. F0 only discriminated sex as females had nearly twice the values for the male informants. Locus Equations (LE) show great isomorphism between the male and female plots. To a greater extent, LE and y-intercepts show that there is greater coarticulation between vowels and preceding stop consonants in Ekegusii with higher regression values that are closer to 1.0 being witnessed for voiceless velar and voiceless labial stops (/k/ and /p/) and the least values for voiceless alveolar stop (/t/).

6.3 Future directions

This study was just the beginning of a systematic scientific study of EkeGusii phonetics. The vowels analysed were measured and documented acoustically hence other ways of describing sounds can be explored by future studies such as articulatory and perceptual analyses. More acoustic analyses need to be conducted on other consonant sounds like nasals and fricatives not covered by this study. Also, due to time and financial limitations, a number of issues concerning vowels and stops were not covered in depth or at all.

The central vowel in Ekegusii /a/ was noted to shift location depending on the regional dialect age and gender of the speaker. More study need to be done also on the vowel shift that can be occurring due to the effect of dominant Kiswahili and English to the sounds of EkeGusii in more recent times.

Also, future research should be done on the other consonants especially using locus equation and regression line. These results can be compared to those found by this study.

Additional data targeting vowels and stops can be done in future studies which will help to confirm or revise findings and conclusions drawn here. It will be even better with a larger number of informants targeting the dialects of Ekegusii.

The phonetics of people with impairments like Specific Language Impairment (SLI), aphasia, stammering and stuttering need to be described and documented. Future studies can also explore with the phonetics of infants and children.

Finally, a comparative study of the dialects of Ekegusii will likely reveal the uniqueness of the seven vowel system of Ekegusii and other related languages. This study could not conclusively put to rest the much touted /t/ - /d/ allophones likely to be prevalent of the Maate dialect of Ekegusii. Tongue positions taken by an informant while producing /t/ for the two dialects need to be investigated using a palatograph or laser images in order to comprehensively describe the differences perceived.

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Appendix 1 Word lists

Table 6.1 List of minimal pairs (or near minimal pairs) to be used in the analysis of duration of Ekegusii vowels in the /tvt/ context alternating short and long vowels

Orthography	**Transcription**	**gloss**
titi	**ti**ti	very (black)
tiiti	**ti:**ti	carry a baby on the back
teta	**te**ta	name of a place
teeta	te:ta	let it not pass
teta	**tɛ**ta	have sex
t**ee**ta	t**ɛ:**ta	have sex for long/repeatedly
tata	**ta**ta	father
taata	**ta:**ta	(calling) father
toti	**tɔ**ti	make soft
tooti	**tɔ:**ti	let us warm/make one to bask
t**o**to	t**o**to	non-word
t**oo**to	t**o:**to	calling 'Toto'
tuti	**tu**ti	name of a place/clan
tuutia	**tu:**tia	a variant of the place/clan name 'Tuti'

Appendix 2 Carrier sentences

Table 6.2 Carrier sentences to be used in the analysis of Ekegusii vowels and stops with highlighted target words.

Sentence	**Transcription**	**Gloss**
Teba **titi** tari **tiiti**	teβa **titi** taɾi **ti:ti**	Say titi and not tiiti
Teba o**tete** tari **oteete**	tɛβa o**tete** taɾi **ote:te**	say Otete not oteete
Tera buna me**tete** **tiga**	tɛɾa βuna mɛ**tɛtɛ** tiɣa	Sing like Metete don't go into a

kobeeteeta	kɔβɛ:tɛ:ta	discord
rora **tata taata** esani	ɾɔɾa **tata ta:ta** esani	See that dad does not break the plate
O**toti** ake **toototi pi**	ɔ**tɔti** ake **tɔ:tɔti** pi	Make the ugali soft
Ototo neyo**tooto**	**ototo** nejo**to:to**	Ototo is good for you
tututi ya sungu**tuuta**	**tutu**ti ja suŋgu**tu:ta**	Nonsensical tongue twister
Ikiiki gaki, iki bionsi.	**iki:ki** ɣaki iki bionsi	Please bring all down
E**keeke nkenga eke gose eke**	E**ke:ke** nkeŋe eke gose eke	This very one is not like this one or this other one
Ekee gekabuga ng'a ekeeke	**ɛkɛ:** ɣekaβuɣa **nŋɛ ɛkɛkɛ**	The bowl made a sound(ideophone)
Ing'a aka amo na**kaaka**	**Inŋa aka** amo na aka:**ka**	Give me this and this one.
Ateba **okooko okooba**?	ateβa **ɔkɔkɔ ɔkɔ:βa**	Did he say okooko delivered?
Aka ekoko no**kooko**.	Aka e**koko** noko**:ko**	Raise an alarm with Okoko
Esu**kubi** yeeri yesukuru**?**	esu**kuβi** yeeri jesuku:ɾu	The hump of a bull.
Akori **pipipi** gaki; yonsi **pipi**.	akoɾi **pipipi** ɣaki jɔnsi pi:pi	He finished completely: everything
E**pe:pe** ye**pep**i.	Epe:**pe** jepepi.	Nonsense words
e**peri** ye epeepe	ɛ**pɛɾi** jɛ ɛpɛ:pɛ	Nonsense words
aka ng'a papapa tari paapaa	aka **nŋa** pa**papa** taɾi **pa:pa:**	Hit like (ideophone).
O**popo bwopooko kai?**	ɔ**pɔpɔ** bwɔpɔ:kɔ kai	Where is Popo son of Opoko's home?
ebi**poopo** bikagwa ng'a p**opo**po.	eβi**po:**po βikagwa nŋa p**opo**po	Eat the whole pawpaw
Aka ng'a **pu**upu tari pupupu	Aka nŋa **pu:**pu taɾi **pu**pupu	Hit like (ideophone)

Appendix 3 Word lists for stop consonants

Table 6.3 List of words used to generate data for the analysis of stop consonants

Orthography	**Transcription**	**gloss**
pi**pi**pi	pi**pi**pi	completely
pa**pa**pa	pa**pa**pa	very hard
po**po**po	po**po**po	ideophone
ti**ti**ti	ti**ti**ti	very black
a**ta**ta	a**ta**:ta	break into small pieces
o**to**to	o**to**to	type of vegetable

i**ki**ki	i**ki**:ki	bring down repeatedly
A**ka**ka	a**ka**:ka	beat/thresh
O**ko**ko	o**ko**ko	name of a person

Appendix 4 List of informants

1. Aggrey Ouko Nyarigoti (Maate) MM3
2. Samwel Ombasa (Maate) MM4
3. Florence Kwamboka Mbera (Maate) MF1
4. Dolphin Bonareri Mose (Maate) MF2
5. Zablon Mireri Nyanumba (Rogoro) RM1
6. Brian Achoki Ombaso (Rogoro) RM2
7. Evelyn Momanyi (Rogoro) RF3
8. Kemunto Omosa (Rogoro) RF4
9. Bruno Obama Nyabuto (Maate) MCM1
10. Ian Sarasi Orina (Maate) MCF1
11. Wilson Asiago Mauti (Rogoro) RCM2
12. Sabina Nyambesa Oyieyo (Rogoro) RCF2

Appendix 5 Raw data

Raw Data for Vowels

7.1 Men informants

RM1	**F0**	**F1**	**F2**	**F3**	**F4**	**DB**	**Short vowel duration**	**Long vowel duration**
i	104	256	2096	2738	3519	61	85	169
e	112	388	1746	2407	3871	56	122	157
ɛ	107	497	1628	2548	3607	62	81	179
a	98	610	1270	2664	3668	58	83	213
ɔ	98	541	1170	2394	3742	60	113	199

o	106	511	1125	2564	3529	61	91	167
u	99	305	1212	1965	3747	54	111	152
RM2	**F0**	**F1**	**F2**	**F3**	**F4**	**DB**	**Short vowel duration**	**Long vowel duration**
i	180	330	2201	2963	4024	81	81	252
e	151	395	2021	2725	4121	83	81	246
ɛ	160	471	1867	2605	4177	84	76	271
a	141	647	1307	2328	4299	80	67	305
ɔ	146	524	1238	2218	3599	84	93	285
o	151	422	1010	2244	3779	84	70	190
u	157	322	1242	2241	3749	81	79	178
MM3	**F0**	**F1**	**F2**	**F3**	**F4**	**DB**	**Short vowel duration**	**Long vowel duration**
i	128	382	1965	2299	3388	70	70	334
e	139	420	2005	2269	2900	76	77	277
ɛ	118	500	1988	2460	3148	64	66	307
a	112	718	1535	2301	3239	64	75	311
ɔ	118	565	1243	2276	2979	65	77	308
o	127	500	1212	2291	3502	69	69	339
u	130	381	1140	2309	3576	71	52	230
MM4	**F0**	**F1**	**F2**	**F3**	**F4**	**DB**	**Short vowel duration**	**Long vowel duration**
i	109	267	2329	3154	4056	74	63	217
e	106	332	2181	2951	4021	80	65	283
ɛ	93	457	1834	3020	3996	78	78	275
a	96	584	1660	2962	4017	79	70	260
ɔ	91	470	1362	2789	3722	78	95	338
o	99	407	1343	2720	3491	79	84	295
u	103	325	1856	2656	3572	78	59	293
Mean for men	**F0**	**F1**	**F2**	**F3**	**F4**	**DB**	**Short vowel duration**	**Long vowel duration**
i	130	309	2148	2789	3747	72	75	243
e	127	384	1988	2588	3728	74	86	241

ɛ	120	481	1829	2658	3732	72	75	258
a	112	619	1443	2564	3806	71	74	272
ɔ	113	525	1253	2419	3511	72	95	283
o	121	460	1173	2455	3575	73	79	248
u	122	333	1253	2293	3661	71	75	213

7.2 Women informants

RW4	**F0**	**F1**	**F2**	**F3**	**F4**	**DB**	**short vowel duration**	**long vowel duration**
i	214	385	2137	2692	3428	79	73	250
e	212	429	1863	2599	3873	78	71	219
ɛ	190	507	1812	2567	4121	79	76	305
a	182	620	1684	2363	4178	78	91	190
ɔ	187	544	1431	2493	4366	81	92	346
o	182	499	1262	2662	4265	80	86	203
u	222	396	1296	2612	3900	80	84	171
RW3	**F0**	**F1**	**F2**	**F3**	**F4**	**DB**	**short vowel duration**	**long vowel duration**
i	274	306	2146	3060	4063	92	75	243
e	273	437	1901	2650	3863	92	106	334
ɛ	236	536	1848	2977	4202	91	118	368
a	226	674	1780	2997	4207	91	110	291
ɔ	233	563	1500	2481	3562	91	144	378
o	249	451	1457	2494	3620	92	118	275
u	235	296	1520	2658	3990	87	75	276
MW2	F0	F1	F2	F3	F4	DB	short vowel duration	long vowel duration
I	225	428	2613	3488	4352	78	90	186
E	216	486	2159	3210	4381	78	88	201

ɛ	210	550	2141	3191	4409	77	92	196
a	205	777	1818	2600	4008	77	79	236
ɔ	208	564	1511	2884	4195	82	112	342
o	216	466	1496	2877	4253	84	102	270
u	216	415	1464	2758	4165	85	74	245
MW1	F0	F1	F2	F3	F4	DB	short vowel duration	long vowel duration
i	199	368	2341	3035	4385	78	66	236
e	188	452	2213	3189	4438	76	97	210
ɛ	191	543	2072	3114	4574	78	93	189
a	202	647	1697	3355	4291	76	104	266
ɔ	186	495	1426	3340	4292	78	115	339
o	185	385	1322	3308	4293	77	114	311
u	193	356	1392	2874	4379	77	84	225
Women's Mean	F0	F1	F2	F3	F4	DB	short vowel duration	long vowel duration
i	228	408	2235	3069	4057	82	76	229
e	222	482	1968	2912	4139	81	91	241
ɛ	207	522	1968	2962	4327	81	95	265
a	204	680	1745	2829	4171	81	96	246
ɔ	204	542	1540	2800	4104	83	116	351
o	208	470	1384	2835	4108	83	105	265
u	217	366	1418	2726	4109	82	79	225

7.3 Children informants

RCM1 Vowels	**F0**	**F1**	**F2**	**F3**	**F4**	**DB**	**Short vowel**	**Long Vowel**
i	409	411	1795	3076	3695	84	100	179
e	404	445	1714	2703	3716	78	94	276
ɛ	397	510	1654	2700	3859	78	91	194
a	349	656	1359	1899	3561	74	105	182
ɔ	344	567	1239	2018	3597	77	107	288

o	337	479	1402	3053	3848	77	86	184
u	320	329	1423	2559	3663	73	73	201
MCM1 Vowels	**F0**	**F1**	**F2**	**F3**	**F4**	**DB**	**Short vowel**	**Long Vowel**
i	229	466	2302	3380	4530	67	74	254
e	245	495	2011	3023	3766	66	84	167
ɛ	243	648	1979	3555	4611	65	95	241
a	225	925	1843	2877	4487	61	68	141
ɔ	228	678	1304	2731	4551	64	83	170
o	259	503	1282	3205	4545	67	88	209
u	196	445	1173	2950	4210	58	85	211
RCF1 Vowels	**F0**	**F1**	**F2**	**F3**	**F4**	**DB**	**Short vowel**	**Long Vowel**
i	265	313	2695	3700	4727	58	94	359
e	265	442	2612	3800	4750	57	112	317
ɛ	274	561	2512	3759	4670	61	110	314
a	258	707	1501	2614	4179	54	77	314
ɔ	248	611	1318	3511	4525	53	92	328
o	383	408	1491	3337	4589	61	102	289
u	254	353	1468	2979	4902	58	93	266
MCF2 Vowels	**F0**	**F1**	**F2**	**F3**	**F4**	**DB**	**Short vowel**	**Long Vowel**
i	218	378	2766	3555	4298	59	94	310
e	221	456	2604	3496	4196	56	101	290
ɛ	274	658	2479	3542	4078	64	90	314
a	218	888	1737	1632	3489	51	91	276
ɔ	248	654	1318	3511	4525	56	87	301
o	383	567	1283	3337	4589	61	89	275
u	254	470	1260	2979	4902	58	90	244
Children Averages	F0	F1	F2	F3	F4	DB	Short vowel	Long Vowel
i	280	392	2390	3428	4313	67	91	276
e	284	460	2235	3256	4107	64	98	263
ɛ	297	594	2156	3389	4305	67	97	265
a	263	794	1535	2256	3929	60	85	228
ɔ	267	628	1295	2943	4300	63	92	272
o	341	489	1365	3233	4393	67	91	239
u	256	399	1331	2867	4419	62	85	231

7.4 Vowel duration for men

Vowel	RM1	RM2	MM3	MM4	Mean
i	85	81	70	63	75
e	122	81	77	65	86
ɛ	81	76	66	78	75
a	83	67	75	70	74
ɔ	113	93	77	95	95
o	91	70	69	84	79
u	111	79	52	59	75
Vowel	RM1	RM2	MM3	MM4	Mean
i:	169	252	334	217	243
e:	157	246	277	283	241
ɛ:	179	271	307	275	258
a:	213	305	311	260	272
ɔ:	199	285	308	338	283
o:	167	190	339	295	248
u:	152	178	230	293	213

8.0 Stop consonant results

8.1a plosives data for women

MW1

plosive	Closure dur	vot	total dur	VR	vowel F0 onset	vowel F0 mid	vowel F2 onset	Vowel F2 mid
pipi	133	10	143	100	246	236	2227	2396
papa	132	8	141	100	236	233	1352	1428
popo	125	8	133	100	234	227	856	926
titi	131	27	158	100	201	197	2340	2391

tata	101	14	115	100	157	155	1678	1640
toto	86	30	116	100	180	182	1278	1343
iki	146	44	190	100	213	197	2541	2536
aka	137	29	166	100	192	187	1634	1376
oko	117	28	145	100	197	187	1135	1333

MW2

plosive	Closure dur	vot	total dur	VR	vowel F0 onset	vowel F0 mid	vowel F2 onset	Vowel F2 mid
pipi	100	9	110	100	231	223	2316	2665
papa	129	8	137	100	230	232	1326	1480
popo	121	7	128	100	239	227	897	951
titi	124	24	148	100	214	197	2351	2418
tata	106	16	121	100	203	155	1647	1656
toto	91	34	124	100	189	182	1251	1336
iki	145	43	189	100	217	197	2541	2563
aka	143	35	178	100	192	187	1496	1368
oko	126	29	155	100	197	187	1064	1280

RW3

plosive	Closure dur	vot	total dur	VR	vowel F0 onset	vowel F0 mid	vowel F2 onset	Vowel F2 mid
pipi	143	8	150	100	284	276	2167	2430
papa	145	8	152	100	247	238	1299	1510
popo	140	6	146	100	239	236	939	1259
titi	146	13	159	100	298	278	2078	1191

tata	157	13	169	100	231	217	1832	1845
toto	166	12	175	100	262	241	1587	1482
iki	166	32	198	100	273	274	1966	2443
aka	170	26	196	100	265	267	1781	1747
oko	158	35	193	100	257	260	986	902

RW3

plosive	Closure dur	vot	total dur	VR	vowel F0 onset	vowel F0 mid	vowel F2 onset	Vowel F2 mid
pipi	143	7	150	100	251	242	2060	2307
papa	135	6	141	100	247	238	1299	1510
popo	142	9	151	100	239	236	939	1259
titi	128	18	146	100	265	257	2120	2215
tata	111	15	126	100	199	197	1674	1648
toto	121	14	136	100	238	227	1496	1367
iki	142	35	177	100	251	252	2349	2348
aka	132	21	153	100	213	211	1635	1639
oko	135	25	163	100	214	211	955	968

8.1b Plosives data for men

RM1								
plosive	Closure dur	vot	total dur	VR	vowel F0 onset	vowel F0 mid	vowel F2 onset	Vowel F2 mid
pipi	140	8	148	100	144	130	2139	2137
papa	149	8	157	100	116	114	929	1079
popo	155	9	165	100	120	121	1129	832
titi	122	22	144	100	119	125	1918	1728
tata	101	19	120	100	119	120	1288	1472
toto	110	14	124	100	122	122	1014	968
iki	111	18	129	100	120	123	1407	1389
aka	107	17	124	100	120	122	1236	1276
oko	153	30	180	100	116	114	861	876

RM2								
plosive	Closure dur	vot	total dur	VR	vowel F0 onset	vowel F0 mid	vowel F2 onset	Vowel F2 mid
pipi	176	12	188	100	142	141	2380	2302
papa	190	8	198	100	135	130	1374	1327
popo	164	8	172	100	122	114	1432	1143
titi	166	36	202	100	143	143	2462	2363
tata	134	18	156	100	130	129	1566	1548
toto	125	15	140	100	130	129	1291	1250
iki	143	59	203	100	141	143	2394	2417
aka	128	36	164	100	108	100	1418	1429
oko	156	43	199	100	112	105	1207	1006

MM3								
plosive	Closure dur	vot	total dur	VR	vowel F0 onset	vowel F0 mid	vowel F2 onset	Vowel F2 mid
pipi	104	7	111	100	113	107	2349	2225
papa	95	5	100	100	114	100	1220	1376
popo	95	6	99	100	107	94	1166	1238
titi	84	18	102	100	106	99	1936	2083
tata	102	10	111	100	96	93	1514	1676
toto	84	11	95	100	93	87	1247	1183
iki	134	47	181	100	112	108	2764	2302
aka	124	28	152	100	106	101	1680	1515
oko	126	44	171	100	103	99	981	1210

MM4								
plosive	Closure dur	vot	total dur	VR	vowel F0 onset	vowel F0 mid	vowel F2 onset	Vowel F2 mid
pipi	113	10	157	100	144	142	2302	2658
papa	104	8	124	100	119	120	1301	1405
popo	99	8	101	100	107	94	1166	1252
titi	83	16	100	100	105	98	1918	2065
tata	103	13	111	100	96	91	1528	1692
toto	83	12	94	100	93	84	1235	1121
iki	130	39	160	100	111	104	2683	2388
aka	126	32	146	100	108	99	1730	1534
oko	128	48	172	100	100	95	901	1160

8.2a VOT Results for women

stop consonants	MW1 VOT	MW2 VOT	RW3 VOT	RW4 VOT	Average
pi	13	12	13	9	12
pa	9	10	7	8	9
po	12	12	9	13	12
mean	11	11	10	10	11
Standard Deviation	2	2	2	2	2
stop consonants	MW1 VOT	MW2VOT	RW3VOT	RW4VOT	Average
ti	27	15	15	26	21
ta	13	15	9	14	13
to	23	16	13	15	17
mean	21	15	13	18	17
Standard Deviation	7	1	3	7	4
stop consonants	MW1 VOT	MW2VOT	RW3VOT	RW4VOT	Average
ki	48	48	37	41	44
ka	23	35	29	28	29
ko	28	38	23	34	31
Mean	33	40	29	34	34
Standard Deviation	13	7	7	7	8

8.2b VOT Results for men

stop consonants	RM1	RM2	MM3	MM4	Average
pi	23	19	20	11	18
pa	16	8	13	9	12
po	22	16	18	13	17
mean	20	14	17	11	16
Standard Deviation	4	6	4	2	2
		VOT			
ti	27	24	25	29	26

ta	23	21	25	25	24
to	25	22	28	28	26
mean	25	22	26	27	25
Standard Deviation	2	2	2	2	1
		VOT			
ki	62	53	46	79	60
ka	29	45	37	37	37
ko	35	48	45	47	44
Mean	42	48	43	54	47
Standard Deviation	18	4	5	22	12

8.3 VOT Results for children

stop consonants	MCM1 VOT	MCF2 VOT	RCM2	RCF1	Average
pi	13	14	16	17	13
pa	7	8	11	12	8
po	11	10	13	13	10
mean	10	11	13	14	10
Standard Deviation	3	3	3	3	3
ti	21	27	25	29	24
ta	15	15	16	22	15
to	13	13	20	26	13
mean	16	18	20	26	17
Standard Deviation	4	7	5	4	6
ki	38	40	44	42	39
ka	28	29	31	33	28
ko	24	20	29	32	22
Mean	30	30	35	36	30
Standard Deviation	7	10	8	6	8

8.4a Vowel F0 following stop burst for women

results for women	MW1	MW2	RW3	RW4	AVERAGE
pi	240	229	235	252	239
pa	233	211	188	247	220
po	216	216	218	241	223
mean	230	218	214	247	227
Standard Deviation	12	9	24	6	10
/t/	Vowel F0 after burst	Vowel F0 after burst	Vowel F0 after burst	Vowel F0 after burst	
ti	193	227	222	269	228
ta	164	213	230	226	208
to	185	219	225	233	216
mean	181	220	226	243	217
Standard Deviation	15	7	4	23	10
/k/	Vowel F0 after burst	Vowel F0 after burst	Vowel F0 after burst	Vowel F0 after burst	
ki	210	223	239	257	232
ka	200	206	218	215	210
ko	203	192	233	215	211
Mean	204	207	230	229	218
Standard Deviation	5	15	11	24	13

8.4b Vowel F0 following stop burst for men

results for men	RM1	RM2	MM3	MM4	AVERAGE
pi	143	143	98	159	136
pa	116	140	102	116	119
po	120	121	151	130	130
mean	126	135	117	135	128
Standard Deviation	15	12	30	22	19
ti	123	146	108	112	122
ta	119	129	92	112	113

to	123	129	92	105	112
mean	122	135	97	110	116
Standard Deviation	2	10	9	4	6
ki	121	142	135	129	132
ka	111	108	137	118	118
ko	112	113	142	117	121
Mean	115	121	138	122	124
Standard Deviation	6	18	4	7	9

8.4c Vowel F0 following stop burst for children

children	MCF2	MCM1	RCM2	RCF2	AVERAGE
pi	256	256	244	214	243
pa	260	257	222	234	243
po	155	155	224	227	190
mean	223	223	230	225	225
Standard Deviation	60	59	12	10	30
ti	238	286	195	233	238
ta	184	185	198	216	196
to	247	247	194	221	227
mean	223	239	196	223	220
SD	34	51	2	9	22
ki	238	239	220	267	241
ka	232	233	223	265	238
ko	244	244	218	266	243
Mean	238	239	220	266	241
SD	6	6	2	1	2

8.5a Burst Intensity of stop consonants for men

Stop burst intensity in Db for men	RM1	RM2	MM3	MM4	Average	SD
pi	60	82	72	76	73	9
pa	72	81	72	77	76	5
po	65	79	77	77	74	6
mean	66	81	74	77	74	6

Standard Deviation	6	2	3	1	2	2

Stop burst intensity in Db for men	RM1	RM2	MM3	MM4	Average	SD
ti	62	77	71	73	71	6
ta	63	77	76	73	72	6
to	65	80	74	74	73	6
mean	63	78	74	73	72	6
Standard Deviation	2	2	3	1	1	1

Stop burst intensity in Db for men	RM1	RM2	MM3	MM4	Average	SD
ki	72	79	77	74	75	3
ka	60	77	79	73	72	8
ko	61	82	79	75	74	9
Mean	64	79	78	74	74	7
Standard Deviation	7	3	1	1	2	3

8.5b Burst Intensity of stop consonants for women

Stop burst intensity in Db for women	MW1	MW2	RW3	RW4	Average	SD
pi	66	68	77	76	72	6
pa	70	70	72	78	72	4
po	65	70	75	69	70	4
mean	67	70	74	74	71	4
Standard Deviation	3	1	3	5	1	2

Stop burst intensity in Db for women	MW1	MW2	RW3	RW4	Average	SD
ti	69	68	71	67	69	2
ta	64	70	72	74	70	4
to	65	75	72	75	72	5
mean	66	71	72	72	70	3
Standard Deviation	3	4	1	4	2	2

Stop burst intensity in Db for women	MW1	MW2	RW3	RW4	Average	SD
ki	65	72	64	67	67	3
ka	66	69	69	65	67	2
ko	63	70	66	65	66	3
Mean	65	70	66	66	67	2
Standard Deviation	2	1	3	1	1	1

8.5c Burst Intensity of stop consonants for children

Stop burst intensity in Db for children	MCF2	MCM1	RCM2	RCF2	Average	SD
pi	72	72	82	88	79	8
pa	74	71	84	86	79	7
po	77	76	83	86	80	5
mean	74	73	83	87	79	7
Standard Deviation	2	3	1	1	1	1

Stop burst intensity in Db for children	MCF2	MCM1	RCM2	RCF2	Average	SD
ti	79	80	84	83	81	3
ta	73	73	85	86	79	7
to	74	74	76	80	76	3
mean	75	76	82	83	79	4
Standard Deviation	3	4			3	0

Stop burst intensity in Db for children	MCF2	MCM1	RCM2	RCF2	Average	SD
ki	78	78	87	84	82	5
ka	71	91	83	83	82	8
ko	71	69	74	82	74	6
Mean	73	79	81	83	79	4
Standard Deviation	4	11	7	1	5	4

9 Running speech results

9.1 results for vowels

9.1a RM1

RM1 running speech vowel results in tVt	**F0**	**F0 SD**	**F1**	**F1 SD**	**F2**	**F2 SD**	**F3**	**F3 SD**	**Intensity**	**Intensity SD**	**short vowel**	**short vowel SD**	**long vowel**	**long vowel SD**
i	135	4	310	4	1975	49	3049	18	79	1	81	8	278	37
e	99	1	354	23	1686	61	2785	302	78	3	80	4	252	38
ɛ	99	3	427	31	1497	68	2588	110	78	1	75	8	223	21
a	133	3	508	9	1289	55	2829	373	82	1	87	17	247	12
ɔ	118	11	412	28	1196	35	2563	133	81	3	75	20	182	24
o	98	1	381	3	1186	31	2707	33	80	1	84	5	203	22
u	100	4	326	45	1266	46	2548	135	77	2	81	9	247	22

9.1b

RM2	F0	F0 SD	F1	F1 SD	F2	F2 SD	F3	F3 SD	Intensity	Intensity SD	short vowel	short vowel SD	long vowel	long vowel SD
i	160	1	320	73	1786	344	2724	247	75	2	80	11	264	52
e	104	5	362	14	1867	205	2623	152	77	2	77	6	208	25
ɛ	107	3	382	6	1677	135	2405	230	75	2	83	15	207	8
a	144	5	481	24	1278	63	1707	214	76	2	84	9	196	17
ɔ	130	1	380	24	1245	3	2493	412	73	3	60	7	153	16
o	102	3	340	16	1209	16	2563	91	72	1	76	21		
													222	22
u	113	3	270	12	1456	62	2380	158	74	3	73	8	192	45

9.2a stop consonant results for MW1

MW1	closure dur	VOT	burst intensity in dB	Vowel F0 after burst
pi	57	19	61	230
pa	49	12	67	222
po	44	13	67	231
mean	50	15	65	228
SD	6	4	4	5
MW1	closure dur	VOT	burst intensity in dB	Vowel F0 after burst
ti	53	25	64	237
ta	42	16	70	220
to	54	18	71	244
mean	50	19	68	234
SD	7	5	4	12
MW1	closure dur	VOT	burst intensity in dB	Vowel F0 after burst
ki	36	40	59	233
ka	68	31	65	234
ko	51	42	56	230
Mean	52	38	60	232
SD	16	6	5	2

9.2b stop consonant results for MW2

MW2	closure dur	VOT	burst intensity in dB	Vowel F0 after burst
pi	50	15	63	249
pa	48	12	65	251
po	42	13	65	246
mean	47	14	65	249
Standard Deviation	4	1	1	2
MW2	closure dur	VOT	burst intensity in dB	Vowel F0 after burst
ti	50	23	67	218
ta	44	15	72	233
to	50	17	72	247
mean	48	18	70	233
Standard Deviation	3	4	3	15
MW2	closure dur	VOT	burst intensity in dB	Vowel F0 after burst
ki	39	43	58	222
ka	52	34	60	237
ko	50	40	67	239
Mean	47	39	62	232
Standard Deviation	7	5	4	9

9.2c stop consonant results for RW3

RW3	closure dur	VOT	burst intensity in dB	Vowel F0 after burst
pi	28	10	64	264
pa	31	10	71	226
po	33	12	63	236
mean	31	10	66	242
Standard Deviation	2	1	4	20
RW3	closure dur	VOT	burst intensity in dB	Vowel F0 after burst

ti	44	14	75	266
ta	32	13	72	230
to	32	15	71	233
mean	36	14	72	243
Standard Deviation	7	1	2	20

RW3	closure dur	VOT	burst intensity in dB	Vowel F0 after burst
ki	53	28	69	223
ka	59	31	75	220
ko	55	27	73	212
Mean	56	29	73	218
Standard Deviation	3	2	3	6

9.2d stop consonant results for RW4

RW4	closure dur	VOT	burst intensity in dB	Vowel F0 after burst
pi	47	17	67	267
pa	47	11	75	218
po	56	15	72	204
mean	50	15	71	230
Standard Deviation	5	3	4	33

RW4	closure dur	VOT	burst intensity in dB	Vowel F0 after burst
ti	55	14	71	214
ta	35	12	78	241
to	35	13	78	210
mean	41	13	76	222
Standard Deviation	11	1	4	17

RW4	closure dur	VOT	burst intensity in dB	Vowel F0 after burst
ki	37	33	72	239
ka	70	29	62	236
ko	67	26	66	250
Mean	58	29	67	241
Standard Deviation	19	4	5	7

9.2e stop consonant results for RM1

RM1	closure dur	VOT	burst intensity in dB	Vowel F0 after burst
pi	31	17	67	163
pa	30	15	74	124
po	26	18	65	109
mean	29	17	69	132
Standard Deviation	3	2	5	28
RM1				
ti	53	38	49	153
ta	53	29	61	128
to	45	32	64	126
mean	50	33	58	136
Standard Deviation	5	5	8	15
RM1				
ki	38	48	58	131
ka	41	25	66	99
ko	34	27	66	134
Mean	38	33	63	121
Standard Deviation	3	13	5	20

9.2f stop consonant results for RM2

RM2	closure dur	VOT	burst intensity in dB	Vowel F0 after burst
pi	37	21	73	150
pa	39	17	77	132
po	33	18	76	118
mean	36	19	75	133
Standard	3	2	2	16

Deviation				
RM2				
ti	43	10	39	75
ta	55	27	67	133
to	34	28	67	124
mean	42	22	57	110
Standard Deviation	18	10	16	31
RM2				
ki	36	36	55	120
ka	39	24	51	100
ko	33	22	53	106
Mean	36	27	53	109
Standard Deviation	3	7	2	10

9.2g stop consonant results for MM3

MM3	closure dur	VOT	burst intensity in dB	Vowel F0 after burst
pi	22	13	69	97
pa	20	13	65	104
po	23	14	67	99
mean	22	14	67	100
Standard Deviation	1	1	2	4
MM3	closure dur	VOT	burst intensity in dB	Vowel F0 after burst
ti	45	27	70	141
ta	40	42	64	115
to	32	20	73	111
mean	39	30	69	122
Standard Deviation	6	11	4	16

MM3	closure duration	VOT	burst intensity in dB	Vowel F0 after burst
ki	30	55	68	111
ka	58	20	65	111
ko	42	29	67	117
Mean	44	35	67	113
Standard	14	18	1	3

Deviation

9.2h stop consonant results for MM4

MM4	closure dur	VOT	burst intensity in dB	Vowel F0 after burst
pi	28	14	72	107
pa	23	13	73	115
po	20	13	71	105
mean	24	13	72	109
Standard Deviation	4	0	1	6

MM4	closure dur	VOT	burst intensity in dB	Vowel F0 after burst
ti	37	42	64	115
ta	43	37	62	115
to	34	26	65	99
mean	38	35	64	109
Standard Deviation	4	8	2	9

MM4	closure dur	VOT	burst intensity in dB	Vowel F0 after burst
ki	48	53	66	107
ka	55	36	76	113
ko	46	37	76	109
Mean	49	42	73	110
Standard Deviation	5	9	5	3

Appendix 6 Plagiarism report

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by otieno peter

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Kisii University
P.O Box 408-40200
KISII

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Following your application for authority to carry out research on ***"Acoustic analysis of Ekegusii vowels and stops"*** I am pleased to inform you that you have been authorized to undertake research in **Kisii and Nyamira Counties** for the period ending **8th October, 2019.**

You are advised to report to **the County Commissioners and the County Directors of Education, Kisii and Nyamira Counties** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

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research in *Kisii* , *Nyamira* Counties

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RE: AWARD OF A DOCTORATE RESEARCH GRANT

Congratulations! The National Research Fund (NRF) has approved a grant of ***Ksh. 450,000.00*** for your ***'Acoustic Analysis of Ekegusii Vowels and Stops'*** Doctorate Research Work.

Our offer of this grant is subject to your agreement to:

1. Use the grant funds only as specified in the approved grant proposal.
2. Maintain, through the grant administering institution your records to show and account for the uses of grant.
3. Allow NRF access the records to verify grant expenditures and activities.
4. Provide written acknowledgment of receipt of payments of grant to the NRF.
5. Repay any portion of the grant not used for the specified purposes.
6. Cooperate with any efforts by NRF to publicize the output of your funded Research work.
7. Comply with reasonable requests for information about your research activities.

The Grant disbursement is subject to you entering into an agreement with the Administering Institution on the above terms among others that the Institution may deem appropriate in the administration of this grant.

Best wishes in implementation of your Research work.

Jemimah G. Onsare, PhD
Ag. CEO, National Research Fund

Copy to: Vice Chancellor, Kisii University

NRF

Funding Research for Sustainable Development