

Analysis of Acoustic Cues in Swahili Language Using Praat Software

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Abstract:- Stress is an extra effort given on a word/phrase to emphasize a special meaning. The acoustic cues for stress include fundamental frequency, amplitude, and duration and vowel quality. The cues vary depending upon the structure of languages. The acoustic correlates of emphatic stress in Swahili language using PRAAT software have not been discovered. Hence the aim of this study is to investigate the acoustic correlates of stress in Swahili language. A total of 30 Swahili speakers from eastern part of Africa within the age range of 18-40 years were selected for the study. Ten bisyllabic words consisting of an adjective and a verb were used. The participants were asked to read the two word phrases with and without stress on the adjectives, to note the variations in stressed and unstressed conditions. The peak fundamental frequency (F0), peak intensity (dB) and duration (msec) were extracted from the adjectives of ten phrases using the PRAAT software version (6.1.09). Statistical analysis using t-test was carried out to see the mean significant difference between males and females for frequency, intensity and duration for both stresses and unstressed. The paired sample t-test was performed to see the significant difference between two conditions of stressed and unstressed with respect to male and female across all parameters was done.

Keywords:- Swahili, Frequency, Intensity, Duration, Praat, Stress.

I. INTRODUCTION

Several studies have investigated the acquisition of the acoustic correlates of stress using different software and stressed syllables are usually associated with one or more of the following properties i.e., raised fundamental frequency, increased loudness, greater duration, and optimizing vowel formant measures for different speaker groups (Ekaterini, Hourri, Ray, Marios, 2018). In languages such as English (Chenauksy,

MacAuslan, Goldhor, 2011), Korean (Hansook, 2002), German (Liisa & Prieto, 2006), Catalan (Tremblay and Owens, 2010). In the Indian context, research on acoustic correlates of stress in words were carried out in Konkani (Kumar, Bhat, 2009), and it was concluded that duration was a cue for stress in Konkani language, Urdu and Hindi (Schertz, Khan, 2020)

Tulu (Shetty, Kumar, 2010), Marathi (Patil, Rao, 2008), Kannada (Narayan, Mahesh, Veeramani, 2019), Tamil (Sangeetha, Savithri, 2012). Among Indo-Aryan languages Hindi, duration and fundamental frequency was observed as the major acoustic correlates of stress. This study focuses on the acoustic cues in Swahili language in both stressed and unstressed perception. To compare the acoustic cues in Swahili, Swahili speakers were recorded speaking both stressed tone and unstressed respectively with manipulated the peak fundamental frequencies (Hz), peak intensity (dB), duration (msec) values. The goals of this research are: to determine peak fundamental frequency (F0), peak intensity (I0) and duration (D0) in Swahili language, to determine the difference or similarity of the acoustic parameters between males and females in Swahili language. Stress in phonetics refers to the emphasis in the form of prominent relative loudness of a syllable or a word as a result of special effort in utterance. Stress provides an acoustic cue to a syllable, word or a part of a sentence to convey different intents without changing the meaning. The acoustic correlates of stress comprises of peak fundamental frequency, intensity and duration length

II. METHOD

2.1 Participants

The participants included in the study were in the age range of 18-40 years. Thirty participants which consisted of 15 males and 15 females were taken for the study. The participants mostly were taken from eastern part of Africa such as Uganda, Kenya and Tanzania who spoke Swahili as their primary native language. The researcher made sure that none of them had any history of speech, language or neurological deficits.

2.2 Materials

The researcher provided each participant with a set of 10 phrases in Swahili as seen in table 1. The phrases consisted of an adjective and a noun.

2.3 Instrumentation

The participants were instructed to read the phrases that were provided, they were also asked to read the phrases exactly as provided in without any disturbances then after used a digital voice recorder for recording. All audios were recorded using PRAAT software (version 6.1.09).

2.4 Procedure

In this research, all participants used the same phrases above in table1. Each person had to do two separate audiorecordings for stressed and unstressed in a quiet room, while recording the stressed audio, they had to stress the adjective of each phrase. Several trials had to be done until we come up with the perfect stressed audio in order to produce the desired output. For the unstressed audio, there was no stressing of the adjective but rather participant had to read the phrases as normal as they are.

No	Word phrase
1	Kijanambunifu
2	Chakulakitamu
3	Mtotomwelevu
4	Nyumbakubwa
5	Baba mkali
6	Mtumaarufu
7	Garinyekundu
8	Chungwabovu
9	Kijanamsumbufu
10	Nguonzuri

Table 1. Ten two- word phrases in Swahili

2.5 Statistical analysis

The descriptive statistics mean, standard deviation is obtained. The data is subjected to Shapiro Wilks test for normality. The results revealed that data is significantly follows normal distribution (i.e., $p > 0.05$). Therefore, parametric tests the mixed analysis of variance- (ANOVA) is carried out to see the significant main effects of gender (male, female), conditions (Stresses and Unstressed) on frequency, intensity and duration separately. Also interaction effect of gender*conditions on these parameters are observed. The independent two sample t- test is carried out to see the mean significant difference between male and female for frequency, intensity and duration for both stresses and unstressed. The paired sample t-test is performed to see the significant difference between two conditions of stressed and unstressed with respect to male and female across all parameter is done. The statistical significant values are compared with 0.05 and 0.01 level of significance. The whole statistical analysis is carried out using SPSS.

III. EXPERIMENTAL ANALYSIS AND RESULTS

3.1 Peak fundamental frequency

To determine peak fundamental frequency (Fo) of males and females in stressed and unstressed conditions in Swahili language.

Table 2: Mixed ANOVA

Variables	df1	df2	F	p-value
Conditions	1	28	22.737	0.000**
Gender	1	28	26.869	0.000**
Gender * Conditions	1	28	1.014	0.323

Table 2, parametric test of mixed ANOVA is carried out to see the significant main effects of gender (male, female), conditions (Stresses and Unstressed) on frequency. Also interaction effect of gender*conditions on these parameters Was observed. Data from Table 2, indicates gender effects and condition effects are significant $p < 0.01$.

The independent two sample t-test is carried out to see the mean significant difference between male and female for frequency.

Conditions	Gender	n	Mean	SD	t(28)	p-value
Stressed	Male	15	176.77	45.37	3.708	0.001**
	Female	15	233.87	38.70		
Unstressed	Male	15	149.70	24.48	6.965	0.000**
	Female	15	216.24	27.73		

Table 3: Independent two sample t-test: Comparison of gender in stressed and Unstressed conditions in Swahili language

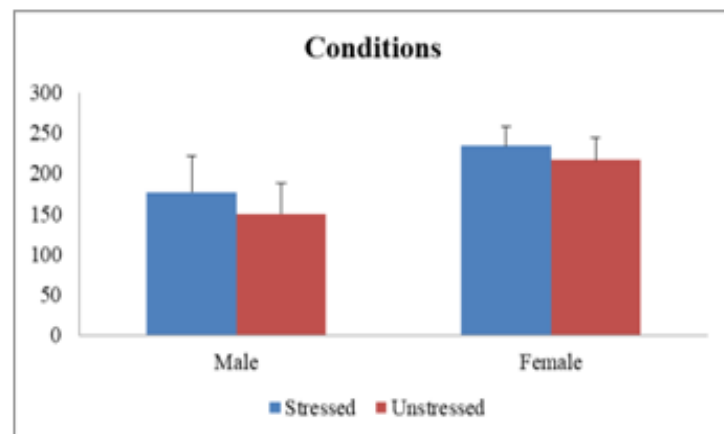


Fig 1:- Gender (male and female) comparison in both S and US conditions in Swahili

As seen from Table 3 and Fig.1 indicates the independent two sample t-test carried out to determine the mean significant difference between male and female for frequency (F0). As observed from Table 3, based on the level of significance, an overall gender effect in both the conditions were significant ($p > 0.01$).

3.2 DURATION

To determine Duration of males and females in stressed and unstressed conditions in Swahili language.

Variables	df1	df2	F	p-value
Conditions	1	28	41.970	0.000**
Gender	1	28	3.358	0.078
Gender * Conditions	1	28	1.165	0.290

Table 4: Paired samples t-test

* Indicates significant at $P < 0.05$ ** Indicates significant at $P < 0.01$, df-Degrees of Freedom

Gender	Conditions	n	Mean	SD	t(14)	p-value
Male	Stressed	15	176.77	45.37	3.315	0.005**
	Unstressed	15	149.70	24.48		
Female	Stressed	15	233.87	38.70	3.831	0.000**
	Unstressed	15	216.24	27.73		

Table 5: Mixed ANOVA

* Indicates significant at $P < 0.05$ ** Indicates significant at $P < 0.01$

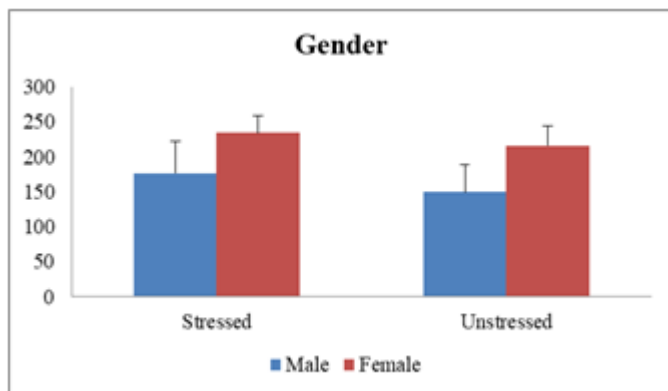


Figure 2. Two conditions of stressed and unstressed with respect to male and female in Frequency (F0).

The pairedsample t-test is performed to see the significant difference between two conditions of stressed and unstressed with respect to male and female in Frequency (F0). As seen from Table 4, statistical analysis revealed the effects of gender (Males and Females) and the conditions of S and US. Using the paired t-test analysis, between males and females in both Stressed and Unstressed conditions show a significant difference ($p < 0.01$). As shown in Table 4, descriptive analysis between males and females in both conditions, the males performed better in stressed ($M =$

176.77; $SD = 45.37$) compared to Unstressed condition ($M = 149.70$; $SD = 24.48$) in Swahili. On the other hand, the females also performed better in stressed conditions ($M = 233.87$; $SD = 38.70$) compared to the unstressed condition ($M = 216.24$; $SD = 27.73$). In this study, peak fundamental frequency show significant difference between unstressed and stressed conditions which correlates with the study done by Roy, Dahit and Mingmar(2019) in study done on Nepali language Hence, reviews support the concept that an acoustic correlate of stress differ across language and depends upon the structure of language.

As seen from Table 5, parametric test of mixed ANOVA is carried out to see the significant main effects of gender (male, female), conditions (Stresses and Unstressed) on Duration. Also interaction effect of gender*conditions on these parameters was observed.

Data from Table 5, indicates that condition effects are significant $p < 0.01$ and gender effects are not significant

➤ The independent two sample t-test is carried out to see the mean significant difference between male and female for Duration.

Conditions	Gender	n	Mean	SD	t(28)	p-value
Stressed	Male	15	26.05	5.12	1.720	0.096
	Female	15	22.63	5.74		
Unstressed	Male	15	19.26	3.61	1.332	0.193
	Female	15	17.78	2.34		

* Indicates significant at $P < 0.05$ ** Indicates significant at $P < 0.01$

Table 6: Independent two sample t-test: Comparison of gender in stressed and Unstressed conditions in Swahili language.

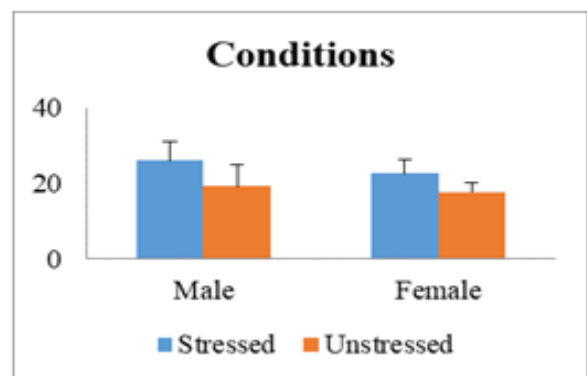


Fig 3:- Gender (male and female) comparison in both Stressed and Unstressed conditions in Swahili

As seen from Table 6 and Fig.3 indicates the independent two sample t-test carried out to determine the mean significant difference between male and female for Duration. As observed from Table 6, based on the level of significance, an overall gender effect in both the conditions were not significant.

Gender	Conditions	n	Mean	SD	t(14)	p-value
Male	Stressed	15	26.05	5.12	5.797	0.000**
	Unstressed	15	19.26	3.61		
Female	Stressed	15	22.63	5.74	3.574	0.003**
	Unstressed	15	17.78	2.34		

Table 7: Paired samples t-test

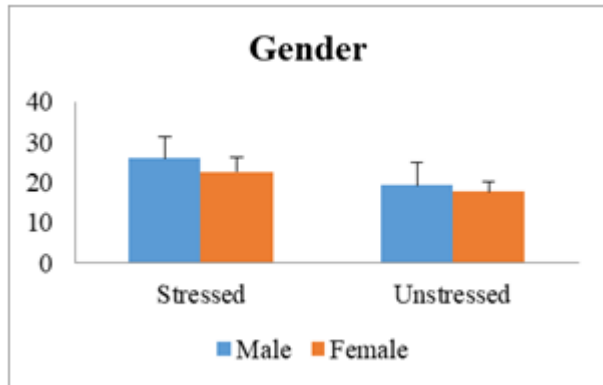


Fig 4:- Two conditions of stressed and unstressed with respect to male and female in Duration.

The paired sample t-test is performed to see the significant difference between two conditions of stressed and unstressed with respect to male and female in Duration. As seen from Table 7, statistical analysis revealed the effects of gender (Males and Females) and the conditions of Stressed and Unstressed. Using the paired t-test analysis, between males and females in both Stressed and Unstressed conditions show a significant difference ($p < 0.01$). As shown in Table 6, descriptive analysis between males and females in both conditions, the males performed better in stressed ($M = 26.05$; $SD = 5.12$) compared to Unstressed condition ($M = 19.26$; $SD = 3.61$) in Swahili. On the other hand, the females also performed better in stressed conditions ($M = 22.63$; $SD = 5.74$) compared to the unstressed condition ($M = 17.78$; $SD = 2.34$). In this study, the mean duration was higher in stressed condition compared to that of unstressed condition which correlates with the study done by Narra, Teja, Sneha, Dattatreya(2012) in study in Tulu language. In the study of acoustic cues in Konkani language by Kumar and Jayashree(2009), duration was also higher in stress and it was considered as a cue of stress in that language.

3.3. INTENSITY

To determine Intensity of males and females in stressed and unstressed conditions in Swahili language.

Variables	df1	df2	F	p-value
Conditions	1	28	5.866	0.022*
Gender	1	28	0.245	0.624
Gender * Conditions	1	28	4.247	0.049*

Table 8: Mixed ANOVA

* Indicates significant at $P < 0.05$ ** Indicates significant at $P < 0.01$, df-Degrees of Freedom

As seen from Table 8, parametric test of mixed ANOVA is carried out to see the significant main effects of gender (male, female), conditions (Stressed and Unstressed) on Intensity. Also interaction effect of gender*conditions on these parameters was observed. Data from Table 8, indicates that condition effects are significant $p < 0.05$ and gender effects are not significant.

➤ The independent two sample t-test is carried out to see the mean significant difference between male and female for Intensity.

Conditions	Gender	n	Mean	SD	t(28)	p-value
Stressed	Male	15	73.85	4.03	-1.031	0.312
	Female	15	75.20	3.08		
Unstressed	Male	15	73.72	3.50	0.120	0.905
	Female	15	73.57	3.20		

Table 9: Independent two sample t-test: Comparison of gender in stressed and Unstressed conditions in Swahili language.

* Indicates significant at $P < 0.05$ ** Indicates significant at $P < 0.01$

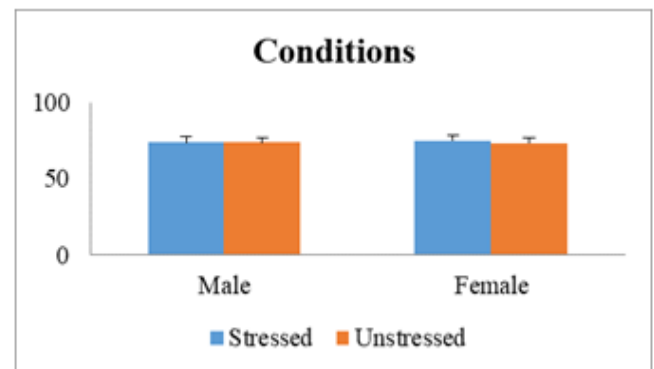


Fig 5:- Gender (male and female) comparison in both S and US conditions in Swahili

As seen from Table 9 and Fig.5 indicates the independent two sample t-test carried out to determine the mean significant difference between male and female for Intensity. As observed from Table 9, based on the level of significance, an Overall gender effect in both the conditions were not significant.

Gender	Conditions	n	Mean	SD	t(14)	p-value
Male	Stressed	15	73.85	4.03	0.216	0.832
	Unstressed	15	73.72	3.50		
Female	Stressed	15	75.20	3.08	4.079	0.001**
	Unstressed	15	73.57	3.20		

Table 10: Paired samples t-test

Indicates significant at $P < 0.05$

** Indicates significant at $P < 0.010000$

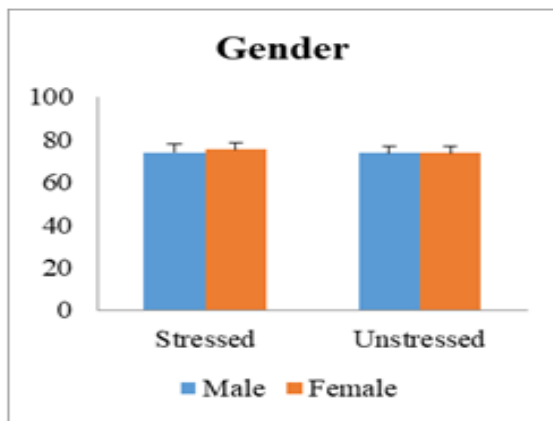


Fig 6:- Two conditions of stressed and unstressed with respect to male and female in Intensity.

The paired sample t-test is performed to see the significant difference between two conditions of stressed and unstressed with respect to male and female in Intensity. As seen from Table 10, statistical analysis revealed the effects of gender (Males and Females) and the conditions of Stressed and Unstressed. Using the paired t-test analysis, between males and females in both Stressed and Unstressed conditions, it showed a significant difference ($p < 0.01$) in females only. As shown in Table 10, descriptive analysis between males and females in both conditions, the females performed better in stressed ($M = 75.20$; $SD = 3.08$) compared to Unstressed condition ($M = 73.57$; $SD = 3.20$) in Swahili. On the other hand, the males also performed better in stressed conditions ($M = 73.85$; $SD = 4.03$) compared to the unstressed condition ($M = 73.72$; $SD = 3.50$). From this study, statistical analysis shows that there is stability in intensity almost no difference between stressed and unstressed between males and females. Similarly in the study done by Vincent J. van Heuven in 2014 in Dutch and English language, it showed uniform intensity differences which made intensity one of the weakest perceptual cues, even though it is acoustically quite reliable.

IV. CONCLUSION

In the present study, acoustic cues using PRAAT software were studied in Swahili speaking adults. The results showed that females showed higher peak frequency in both stressed and unstressed conditions in terms of comparison of gender. Furthermore, in conditions of stressed and unstressed with respect to male and female, males had a higher peak frequency in stressed compared to unstressed conditions. In comparison if gender in duration, males had higher duration in stressed condition than females in both stressed and unstressed. According to observation based on level of significance in comparison of gender, an overall gender effects in both the conditions were not significant.

In conclusion. The results visualize that there is a significant increase in peak fundamental frequency and peak intensity repeatedly, in stress condition. Thus, it is possible that a Swahili speaker uses peak fundamental frequency and peak intensity as a cue hence to frequency and duration are better acoustic cues in Swahili language. This information

would enable us to understand acoustic correlates of stress in Swahili language, make further research on the language as well as helping in the forensics department in Uganda and East Africa as well.

➤ Acoustic parameters

1. Peak fundamental frequency (f_0) was measured as the maximum pitch in the utterance in Hertz (Hz)
2. Peak Intensity (I_0) was measured as the maximum intensity in the utterance in dB.
3. Duration (D_0) was measured as the time difference between the starting and end point of the utterance in milliseconds.

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