5-2020

Vowel Intelligibility of Saudi Spoken English

Mahdi Duris
St. Cloud State University

Vowel Intelligibility of Saudi Spoken English

by

Mahdi Duris

A Thesis

Submitted to the Graduate Faculty of

St. Cloud State University

in Partial Fulfillment of the Requirements

for the Degree of

Master of Arts in

English: Teaching English as a Second Language

May, 2020

Thesis committee:
Ettien Koffi, Chairperson
Edward Sadrai
Joy McKenzie

Abstract

This thesis serves two purposes. The first is to describe Saudi-accented English vowels acoustically. The second is to rely on the measurements obtained from the acoustic phonetic analyses to assess the intelligibility of their vowels. The methodology pioneered by Peterson and Barney (1952) and replicated by Hillenbrand, Getty, Clark & Wheeler (1995) in their studies of General American English (GAE) is adopted in this study. However, unlike the two previous studies that measured vowels in citation forms, this study measures the acoustic correlates of vowels in running speech style. The participants are 32 Saudi educators who teach English as a Foreign Language (EFL) in the Kingdom of Saudi Arabia: 23 females and 9 males. They were recorded reading a longer version of the GMU Speech Accent Archive text. The analysis focuses on the 11 monophthong phonemic vowel of English. Three different words containing each one of the 11 vowels under consideration were isolated, annotated, and measured for F0, F1, F2, F3, F4, intensity and duration. The software program used is Praat. The annotation and feature extraction were done manually to minimize errors. The first (F1) and second (F2) formants were used to create acoustic vowel spaces. Intelligibility assessments are based on Koffi's (2019) Acoustic Masking and Intelligibility (AMI) theory. He contends that intelligibility of vowels can be measured instrumentally by comparing the F1 of vowels because this formant carries 80% of the acoustic energy found in vowels. The AMI theory also combines Just Noticeable Differences (JND) thresholds and Relative Functional Load (RFL) calculations to gauge severity of masking and intelligibility. Using this approach, the intelligibility of Saudi-accented vowels is assessed in two ways: internally and externally. Internal masking analyses focus on whether or not Saudi speakers differentiate clearly among the English vowels when they speak. External masking focuses on whether or not the vowels produced by Saudi speakers mask the vowels produced by GAE speakers. The findings discussed in this thesis are based on 7,392 measured tokens. The pedagogical implications and applications recommended in this thesis are data-driven. The most important insights that one can glean from this study is the *kiss* vowel [ɪ], the *foot* vowel [ʊ], and the *trap* vowel [æ] are the most problematic vowels for Saudi speakers of English. Since the RFL of [ɪ] and [æ] are particularly high, it is recommended that the pronunciation of these two vowels be prioritized in instruction.

Keywords: L2 Speech Intelligibility, Vowel Intelligibility, Masking Analysis, Acoustic Phonetics, Arabic-accented English, Just Noticeable Differences, Relative Functional Load, Masking, AMI

Acknowledgment

بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

In the name of Allāh, Most Merciful, Bestower of Mercy. All praise is due to Allāh, Lord of all creation. To proceed. The Messenger of Allāh ﷺ said: “He does not thank Allāh, he who does not thank the people.” After thanking Allāh ﷻ for His blessings and bounties upon me, I would like to extend my deepest gratitude to the following people.

In the midst of the first global pandemic (COVID-19) of the 21stcentury, I wish to recognize the leadership of St Cloud State University (SCSU), the State of Minnesota and World leaders in choosing the preservation of life over any other subsidiary affair of this world. I would like to thank the TESL faculty of SCSU led by Dr. Robinson for giving me the resources to thrive in a master’s program. My appreciation goes to Dr. Schwartz and Julie Condon for supporting me as a teacher in their English for Academic Purposes program.

My appreciation to all the participants of this study. You must remain anonymous; however, your willingness to participate was a great show of courage and confidence. Indeed, being a Saudi English teacher comes with a lot of challenges from within.

I am grateful to my thesis committee members. Professor Joy McKenzie for her insights as a Speech Language Pathologist. To Dr. Ed Sadrai for your class on theories of Second Language Acquisition. Your class reframed my appreciation for the cognitive demands of speaking three languages as a child. Upon my interest of researching accentedness, you guided me to the works of Dr. Koffi and Dr. John Levis. To Dr. Koffi, I am indebted for your patience, academic writing coaching, marital advices and above all, your humanity. You supported me through my thesis with patience and attention to details. Because of your recommendation, I will continue my research in the field of intelligibility at Iowa State University.

I am thankful to my parents, Karine Noelle Fernandez and Jean-Louis Duris for their unwavering support through my countless academic failures as a child. I know this makes you proud. To my wife, best friend, graduate study coach and unconditional supporter, Momina Khālid daughter of Khālid Mas'ūd. No words or space on these pages could describe how much you have helped me and Allāh knows best.

The errors that are found herein are mine alone.

Table of Contents

Page

Appendices Page

List of Tables

Table Page

List of Figures

Chapter I: Introduction

Chapter Introduction

"I want to speak like an American." This would be the unanimous answer of most Saudi educators when I asked them what they would change about their spoken English. I would smile and ponder why it was so important to them. After living for five years in the Kingdom of Saudi Arabia, performing various academic roles for English as a Foreign Language (EFL) programs, it was clear that these teachers' main objective was clarity and fluency of spoken English. They were more concerned; however, with how long it would take to identify their gaps. This was confirmed when I observed them in their classrooms attempting to tackle pronunciation only to fall shy because of how they sounded. When I was introduced to the field of acoustic phonetics, I immediately connected my studies to the needs of these Second Language (L2) teachers and a possible solution: an individualized measurement of their speech production that could efficiently determine intelligibility issues. Acoustic measurements allow us to target the features of an individual's speech intelligibility and in English intelligibility can be increased by focusing on vowels. The academic consensus on vowels is best resumed by Prator and Robinett (1972, p. 13): "if you wish to understand and be understood in English, you must be able to distinguish and make the distinction among the vowels sounds with great accuracy."

This research focuses on an acoustic phonetic analysis of the vowels of Saudi university educators and specifically teachers of EFL. By providing such analysis, a clear picture is made available on the similarities and differences of Saudi produced English vowels. In that regard, this is the first acoustic phonetic inventory of such participants. Measurement of their vowels uncovers potential intelligibility issues from their speech. Such analysis is important in order to provide Saudi educators with a clear representation of gaps in Saudi spoken English while providing pedagogical solutions.

First, Saudi spoken English vowels from 32 participants are analyzed by mapping a clear picture of their acoustic characteristics. The study continues with a contrasting analysis of Saudi vowels to General American English (GAE) vowels. This information highlights the gaps in acoustic distances from both Saudis and Americans which are indicators for intelligibility. Finally, intelligibility assessments are performed to determine which vowels may cause poor intelligibility by way of complete acoustic masking. Based on these measurements, we can propose a complete picture of the vowel intelligibility of Saudi spoken English. The research concludes with pedagogical recommendations based on the most salient intelligibility findings for Saudi educators.

As the first study to exclusively focus on Saudi spoken English vowels in running speech, this work is timely relevant as the Kingdom of Saudi Arabia enters the last part of the *Vision 2030* phase. In this nationwide strategy, emphasis is being shifted to Saudi teachers of EFL to educate Saudi youth. This was a role primarily given to expatriates from Inner Circle countries. With the intention of shifting its economy away from oil resources, KSA is looking inward for EFL educators. The conclusions of this study will provide direct instrumental measures of the potential intelligibility issues that may need immediate attention.

Literature Review

A focus on vowel is deliberate as it highlights many features unique to English and potentially difficult for L2 speakers. In English, “vowels are a primary element of the syllable (i.e., nucleus)” (Fogerty & Humes, 2012, p. 1492). As found in Koffi (2019a, p. 90), acoustic phoneticians such as the late Ladefoged (2006), underlined that "accents of English differ more in their use of vowels than in their use of consonants" (p. 38). Past measurements relied on the Peterson and Barney (1952) and Hillenbrand et al. (1995) isolation vowel models to study participants. This study will focus on running speech to capture a more realistic, everyday classroom type of speech. Considering that Saudi learners of English must acquire vowels that are non-existent in Arabic (Al-Eisa, 2003), it is expected that some unfamiliar English vowels (Khalil, 2014) would also lead to poor intelligibility. To assess intelligibility, this study follows the rigorous theory set forth by Koffi (2019a, p. 73), which is specifically developed for L2 data, called the *Acoustic Masking and Intelligibility (AMI)* theory. The AMI theory states that "if vowel segments are acoustically too close to each other to be distinguishable, an auditory masking may occur if their phonemic lexicon load is significant" (p. 73). The AMI theory offers a robust acoustical phonetic measurement of intelligibility which departs from impressionistic rating values. Such theory has been used to distinguish intelligibility in L2 spoken English previously. These intelligibility studies focused on Nepali (Koffi, 2019b), Mandarin (Koffi, 2019c and Ma, 2018), Panamanian (Koffi & Gonzalez Lesniak, 2019), Salvadorian (Peña Coreas, 2019) and Somali (Koffi, 2012).

Overview of Arabic Vowels. In order to highlight fundamental differences and similarities between Arabic and GAE, we will first look at the Arabic vowels. These highlights do not impact the study of vowel intelligibility but provide essential L1 background information. Arabic speakers are part of a diglossic community that "can be classified into high level MSA[1] or *al fusha'* and low level colloquial of *al 'amiya* strains" (Zahrani, 2017, p. 1). Research

---

[1] Modern Standard Arabic

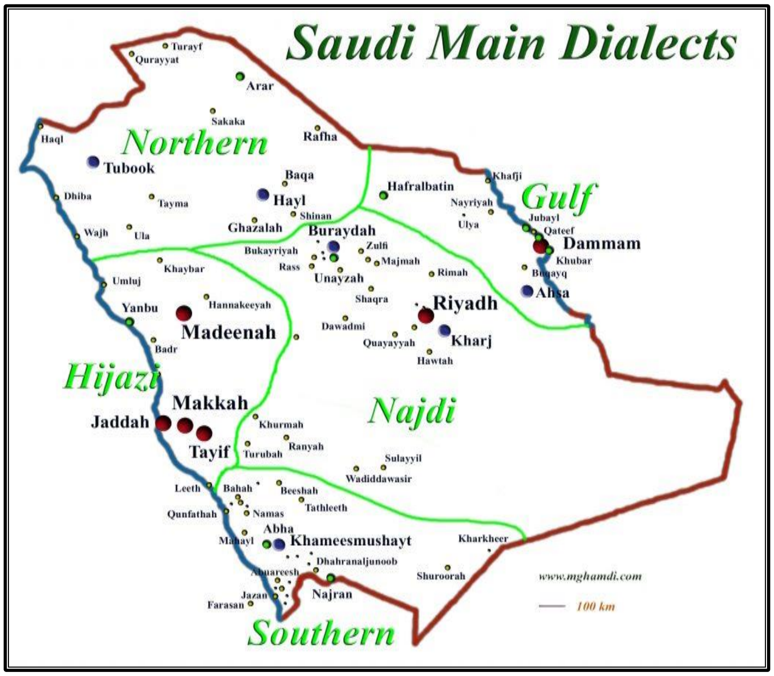
regarding Arabic vowels has progressed; however, a full standardized consensus of phonemic vowels actually produced by Arab speakers is not available. The predominance of Arabic literature and writing has greatly reduced the scope of Arabic language linguistics to what is written and not what is said. Abu-Rabia (1999) makes a case that the Arabic alphabet does not contain vowels and having the ability to read Arabic without diacritic marks (short vowels) is regarded as “an advanced ability” (p. 97). Arabic learners are taught to focus more on consonants. This further removes the saliency of vowels in their L1. This was made relevant to me in a class attended by an Arab native speaker, while he was asked if Arabic has vowels, he replied: “There are no vowels in Arabic.” He was referring to the writing of Arabic not containing diacritic marks while his awareness of the phonemes was absent.

Several models have been proposed for Arabic vowel representations which have been detailed by Khalil (2014, pp. 9-13). The smallest inventory describes Arabic having three vowels, which the International Phonetic Association (2010, p. 11) represents as /a, i, u/. The next model uses six vowels which are /a, a:. i, i:, u, u:/ (Kotby, Saleh, Hegazi, Gamal, Abdel Salam, Nabil & Fahmi, 2011 and Saadah, 2011). A third model adds two diphthongs to the previous six for eight total vowels: /a, a:, i, i:, aɪ, u, u:, aʊ/ (Alotaibi & Hussain, 2010). Finally, Al-Eisa (2003, p. 42) proposed a ten-vowel model for Arabic vowels which include: /a, a:, e, e:, i, i:, o, o:, u, u:/. She consequently gave a precise description of Arabic vowels as: “more importantly, Arabic lacks all the lax vowels found in English, that is / ɪ/, /ɛ/, /æ/, /ʌ/, /u/, /ʌ/, /ɔ/ and /ə/. Though classical Arabic lacks mid vowels, some Arabic dialects have the mid vowels /e/, /o/, /o:/ and /e:/. So, English tense mid vowels do not really cause problems to Arabic speakers” (p. 42).

KSA's diglossia highlights many dialects amongst its low variety of colloquial Arabic. This is an added factor to consider in the vowel inventory of Saudi Arabic speakers. The major dialects present in Saudi Arabia today are shown below in Figure 1.1.

Figure 1.1

Dialects of Colloquial Arabic in KSA[2]



After consulting with Dr. Mansour Alghamdi, an acoustic phonetician from the Kingdom of Saudi Arabia, his consensus on the inventory of Saudi Arabic vowels after 20 years of research is proposed in the following table (Table 1.1).

[2] Provided by Dr. Mansour Alghamdi on March 28th, 2020

Table 1.1

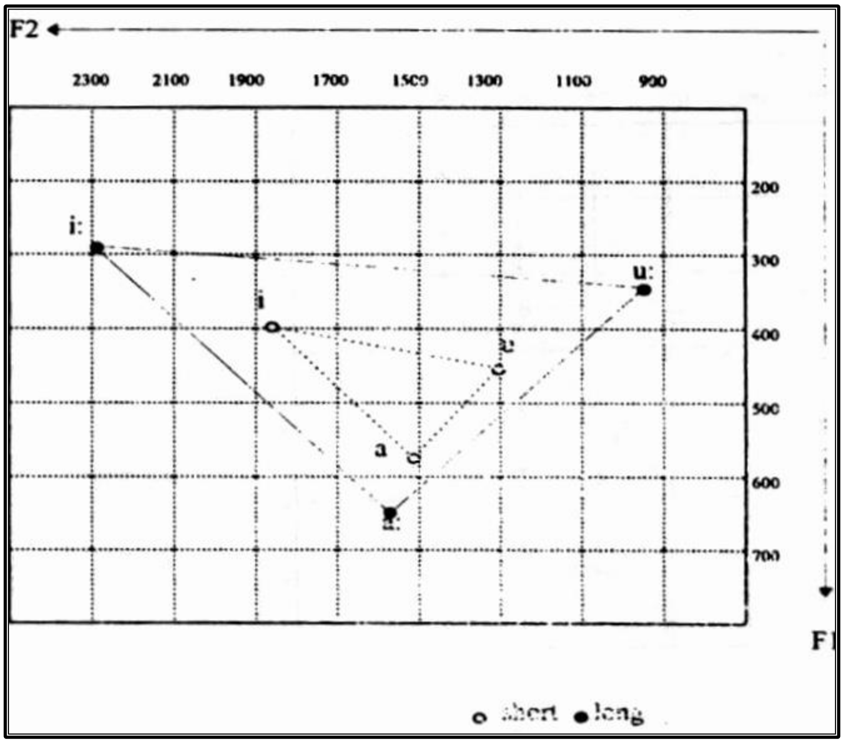
Arabic Twelve Vowel Phoneme Model

	Front	Central	Back
High	i: (Yaa)		(Wauw) u:
	i (Kasra)		
		(Damma) u	
Mid			
		(Fatha) a	
		(Alif) a:	
Low			

In his analysis of Saudi vowels, Alghamdi (1998, p. 5) gives a vowel space account of the 6 vowels of Saudi Arabic in an isolated CVC syllable form. The vowels /i:, a:, u:, i, a, u/ were placed between two /s/. The participants were 5 Saudi males with an average age of 35 years old. Figure 1.2 shows their vowel space (Alghamdi, 1998, p. 22).

Figure 1.2

Vowel Space for Saudi Arabic



General American English Vowels. With eleven phonemes, English ranks high on the vowel numbers compared to other languages. As mentioned by Koffi (2019a, p. 90), the repository of cross-linguistic phonological inventory data, also known as PHOIBLE has inventoried 266 languages having systems of 3 to 9 vowels. Acquiring eleven vowels is a challenge for non-native speakers, specifically for Arabic natives. The spoken varieties of Arabic are numerous and contain many vowel differences.

Two major studies have provided measurements of vowels using acoustic phonetic instruments for GAE. The first in 1952 by Peterson and Barney focused on “ten monosyllabic words which began with [h] and ended with [d] and which differed only in the vowel” (Peña Coreas, 2019, p. 10). This study of isolated speech gave precise measurements of vowel formants (first and second) which are essential for accurate analysis. Ladefoged & Johnson (2015, p. 221) describes these formants and the information they give us: “spectrograms are usually fairly reliable indicators of relative vowel quality. The frequency of the first formant certainly shows the relative vowel height quite accurately. The second formant reflects the degree of backness quite well.” The second major study of vowels was completed in 1995 by Hillenbrand et al. reinforcing the 1952 study by including “sounds for the Midwest” and “vowels /e/ and /o/” (Peña Coreas, 2019, p. 12). These GAE vowel[3] measurements will be used for this study as a reference in contrasting Saudi English vowels and GAE vowels. Table 1.2 details the GAE vowels:

Table 1.2

GAE Vowel Quadrant (Koffi, 2019a, p. 9)

	Font	Central	Back
High	/i/ <see>		/u/ <sue>
	/ɪ/ <sit>		/ʊ/ <soot>
Mid	/e/ <say>		/o/ <soak>
	/ɛ/ <set>		/ɔ/ <salt>
Low		/ʌ/ <such>	
	/æ/ <sat>		/ɑ/ <sod>

Intelligibility Assessment. In order to assess intelligibility, it has been a common practice to let human raters judge the speech of L2 English speakers. Since we are conducting an acoustic phonetic analysis of Saudi English, using their data to assess intelligibility would give us direct access to a non-impressionistic judgment of their speech. Such methodology has been used quite extensively and to date, the most data heavy work on L2 intelligibility has been done

[3] The rhotic vowel or “vocalic r” will not be included in this study.

by Koffi (2019a). The manuscript details over "11,000 measured tokens produced by 10 GAE and 67 non-native speakers of English" (p. 57). The methodology used to assess intelligibility for this study will replicate much of Koffi's (2019a) work. We will first point to the most relevant formant to assess intelligibility, which is F1. Secondly, the relevant acoustic threshold, called Just Noticeable Difference (JND) will be used to determine any problematic vowels (Appendix A). Lastly, we will measure a speaker's intelligibility by way of masking[4], combined with a Relative Functional Load (RFL) consideration, to determine the severity of unintelligibility.

Vowel height is the most salient formant to measure intelligibility as Fogerty and Humes (2012, p. 1490) describe: "the data suggest that the acoustic information present during vowels is essential for speech intelligibility." This was also mentioned previously from Ladefoged and Johnson (2015, p. 207) that F1 carries 80% of the energy in a vowel. For the purpose of answering the research questions, focus will be given to F1 as a measure of intelligibility of Saudi English vowels. The thresholds in which intelligibility measurement are salient have been distinguished by Koffi (2019a, p. 92) and pertains to the acoustic distance needed between two phonemes. By quoting Labov, Rosenfelder & Fruehwald (2013, p. 43), Koffi explains that they "have used the acoustic threshold of 60 Hz as a robust acoustic criterion for distinguishing between perceptually similar vowels" (p. 92). Any distance ≥ 60 Hz is deemed as that no masking has occurred and "intelligibility is optimal." If the distance is less than 60 Hz then "masking is likely." Furthermore, "complete masking occurs when the F1 distance between two vowels is ≤ 20 Hz" (Koffi, 2019a, p. 93). Additionally, we will highlight complete masking

[4] Masking as described by Fletcher (1953, p. 153):"If while a sound A is being impressed upon the ear, another sound B is gradually increased in intensity until the sound A can no longer be heard, the sound A is said to be masked by the sound B. The sound A will be called the 'maskee' tone and the tone B the 'masker' tone."

measurements (≤ 20 Hz) for intelligibility analysis. In order to give a complete intelligibility assessment, the use of a Relative Functional Load (RFL) measurement will be further applied. The RFL table presented by Koffi (2019a, p. 67) details 54 vowel phonemes pairs and their lexical load in English (Appendix B). For example, vowel phonemes [i] and [ɪ] carry a load of 95% which could cause severe unintelligibility while pair [ʊ] and [o] only carry 12% RFL which is not problematic for intelligibility. The following theory by Koffi (2019a, p. 73) is used for systematic intelligibility assessments with RFL:

> Acoustic Masking and Intelligibility (AMI): segments that are acoustically close may mask each other with only a minimal risk to intelligibility, unless their relative functional loads dictate otherwise.

The last component to a complete acoustic phonetic intelligibility assessment revolves around distinguishing between internal masking and external masking (Koffi, 2019a, p. 94). Internal masking pertains to the intelligibility assessment of the vowels of a speaker. If a speaker's two vowels do not have an optimal JND distance of > 60 Hz, this signals that the speaker does not distinguish these two vowels in his/her own vowel space. This is called an internal masking. Furthermore, intelligibility issues between a speaker's vowels and a hearer's vowels are called external masking. Table 1.3 below summarizes the main components for intelligibility assessment used for this thesis:

Table 1.3

Intelligibility Assessment Matrix (Koffi, 2019a, p. 93)

#		F1 Distance	Masking Levels		RFL		Intelligibility Rating
1.		> 60 Hz	No masking		0-24%		Good intelligibility
2.		41 Hz – 60 Hz	Slight masking		25-49%		Fair intelligibility
3.		21 Hz – 40 Hz	Moderate masking		50–74%		Average intelligibility
4.		0 Hz – 20 Hz	Complete masking		75–100%		Poor intelligibility

It is important to remind the benefits of intelligibility assessments by way of acoustic measurements for L2 learners and educators over aural ratings using Koffi's (2019a, p. 88) own words:

> Finally, intelligibility of L2-accented English as envisioned in this book is similar to machine driven speech recognition. Whether the interlocutor is a human being or a machine, intelligibility is assessed based on how closely the acoustic phonetic signals that the talker emits match the template(s) in the mind of the hearer or those in the "mind" of the software.

Methodology

Research Questions.

1. What are the acoustic phonetic characteristics of Saudi-accented English vowels?
2. How similar or different are the 1^{st} and 2^{nd} formants when compared to GAE vowels?
3. Do the differences in vowel height measurements (F1) interfere with intelligibility?

Participants. The participants for this study are 32 Saudi adults: 23 females and 9 males. The age of these Non-Native Speakers (NNS) varies between 19 to 53 years old. All of them reside in the capital city of the Kingdom of Saudi Arabia (KSA), Riyadh. All female participants are English as a Foreign Language (EFL) teachers at the world's largest female-only university. All male participants are EFL educators in Higher Education institutions. Such universities as, all female student body, Princess Nourah bint Abdulrahman University (PNU) and all male student body, King Saud University (KSU). The 32 participants were divided into two subgroups based on biological genders. Biological differences are highlighted to provide greater insight in phonetic analysis. As noted by Kent & Read (2002, p. 194), male vocal tracts are longer than female which leads to lower formant frequencies. The consequences of such differences are relevant for both the first and second formants when vowel boundaries are defined. Additional important details on the linguistic profile of these participants are shared below.

All 23 female participants are born of Saudi parents. Most of them (73%) were born in Riyadh while only one participant was born overseas in Canada. Ten of the 23 participants of lived their whole lives in KSA. Of those who lived in an Inner Circle country (56%), the majority did so as adults. Participants have first started to speak English on average around 10 years old and their median age is 32 years old. They attribute "entertainment in English" as their main contributor to English-speaking fluency. Appendix E provides more details.

Male participants, similarly, are all born from Saudi parents. Most of these educators were born in Riyadh and only one was born overseas in the United States. Most of them have lived in an Inner Circle country for an average of 6 years. Only one participant spent his childhood there. Male participants started speaking English on average at age 15 and their median age is 32 years old. For the majority, "speaking with natives" is the biggest factor to their English speaking fluency. Appendix F offers a complete set of data.

Participation was on a voluntary basis and agreed upon by way of a signed International Review Board consent form (Appendix L).

Description of Data Collection Instruments. To capture the acoustic phonetic properties of each participant, a SONY ICD-UX560F (2018-12) voice recorder was used to gather MP3 formatted stereo samples (sample rate of 44.1 kHz).

Headphones with a fixed microphone was used when recording. The headset used is a G231 Prodigy gaming, model A-00060. The microphone type is Cardiod (unidirectional) with a frequency response between 50 Hz and 20,000 Hz. The recorded participant samples were analyzed using a free software designed to extract phonetic features from digital recordings named Praat (Boersma & Weenink, 2019). Specifically, software 6.0.48 was used to measure the acoustic correlates of F0, F1, F2, F3, F4, intensity and duration of the participant's vowels. To do so, sample sounds were converted from stereo MP3 formats to the Praat accepted WAV mono file with a sampling frequency at 44,100 Hz.

Procedures. The methodology for this study replicates a similar one used by Koffi and Gonzalez Lesniak (2019) by extracting vowel measurements from the following elicitation paragraph (Appendix C):

> *Please call Stella. Ask her to bring these things with her from the store: Six good spoons of fresh snow peas, five thick slabs of blue cheese, and maybe a foot-long sandwich as a snack for her brother Bob. We also need a small plastic snake, the little yellow book, a rubber duck, and a paper I-pad. She should not forget the dog video game and the big toy frog for the kids. She must leave the faked gun at home, but she may bring the ten sea turtles, the mat that my mom bought, and the black rug. She can scoop these things into*

three red bags and two old backpacks. We will go meet her, Sue, Jake, and Jenny, Wednesday at the very last train station. The station is between the bus stop and the cookie store on Flag Street. We must meet there at 12 o'clock, for sure. The entrance is at the edge of the zoo in Zone 4 under the zebra sign. York's Treasure Bank is the tall building in the left corner. She cannot miss it.

The text encompasses all the General American English (GAE) vowels. It was originally proposed by George Mason University for the Speech Accent Archive (http://accent.gmu.edu/howto.php#cite). However, Koffi (2019a) expanded it to include a missing [ʊ] vowel and at least three repetitions of the same vowel in different consonant vowel combinations. The recordings were made in quiet rooms to avoid any background noise. The relative position of the microphone to each participant's mouth was similar in distance to avoid any sound recording inconsistencies.

A point of departure from the standard methodology "that has been replicated hundreds of times to study vowels in L1 and L2 English" (Koffi, 2019b) is in the participants vowel production. Traditionally, isolated monosyllabic words are used to highlight the vowel being measured by constraining them between an /h/vowel/d/ context. The highlight is due to the /h/ being a "voiceless consonant that has weak noise" and the /d/ sound being a "stop consonant" (Khalil, 2014, p. 19). A case should be made for the advantages of using running speech in vowel measurements, specifically when contrasting them with L2 spoken English. Isolated speech presents two disadvantages for L2 participants. The lack of context for a word might prove difficult for L2 speakers. Specifically, from the list of isolated words used in past studies, we find: "hod," "hawed," "who'd," "hud" and "hoed." Secondly, the phonemic awareness needed for such production is quite limited in L1 and even more in L2 English. By using running speech, to capture vowel production of L2 English, two advantages become apparent. Target words are in context which increases naturalness of speech. Secondly, the words targeted are frequently used and accessed by L2 learners. Advantages of running speech over isolated words are described by Fogerty and Humes (2012, p. 1493) as follows:

> The relative contribution of vowels is different in isolated words than it is in sentences. Vowels provide large benefits over consonants for speech intelligibility of sentences (Kewley-Port et al, 2007; Fogerty and Kewley-Port, 2009), yet no such difference is apparent in isolated words (Owren and Cardillo, 2006; Fogerty and Humes,2010).

Previous intelligibility research has used a running speech model to measure L2 produced vowels successfully. Such study (Koffi & Lesniak, 2019) established that using running speech with isolated word measures are acoustically permissible.

As stated in Koffi & Lesniak (2019, p. 58):

> In other words, Ladefoged et al. (1976) findings indicate that producing vowels in isolation and producing them in running speech have no impact on intelligibility. The duration and frequency thresholds examined above tell us that it is acoustically permissible to compare and contrast vowels in citation form and those in running speech. Doing so is not like comparing "apples and oranges."

Analysis

Praat was used for the analysis and measurement of the vowel production of the participants. For each vowel measured, three sets of words were extracted and analyzed from the elicitation paragraph. Table 1.4 below shows which words have been used for each vowel measurements, along with the corresponding vowel name.

Table 1.4

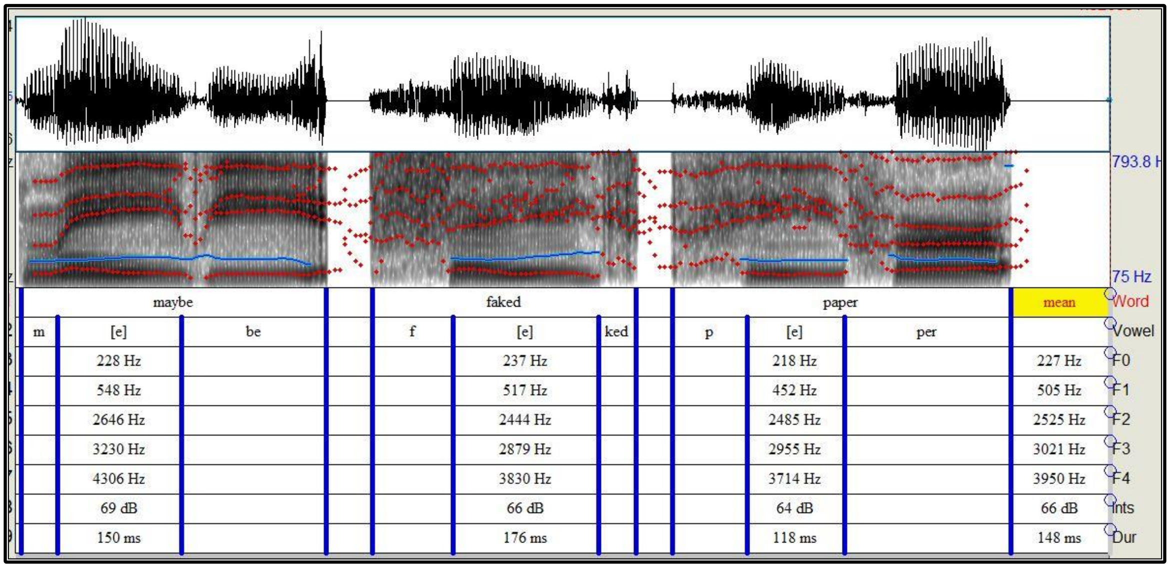
Vowel Sound Names

Vowel sound and name										
fleece	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**foot**	**goose**	**strut**
[i]	[ɪ]	[e]*	[ɛ]	[æ]	[ɑ]	[ɔ]	[o]*	[ʊ]	[u]	[ʌ]
Text equivalent										
please peas meet	with thick is	maybe faked paper	yellow edge red	ask pad mat	Bob dog frog	for bought corner	old go zone	good book cookie	blue scoop zoo	rubber duck must

The measurements of 11 vowels produced 3 times for 32 participants were analyzed. The first step in analysis consisted of splicing the extracted vowel audios into one single audio file corresponding to the vowel sound. Then, spectrographs were created using Praat which showed measurements for the correlates F0, F1, F2, F3, F4, intensity and duration of each word in the vowel set. All in all, the data for the analysis consisted of 7, 392 tokens, that is, (11 vowels x 3 repetitions x 32 participants x 7 correlates). Figure 1.3 shows an example of a participant spectrogram for vowel sound [e].

Figure 1.3

A Spectrogram for Vowel [e] Set: Maybe, Faked, Paper



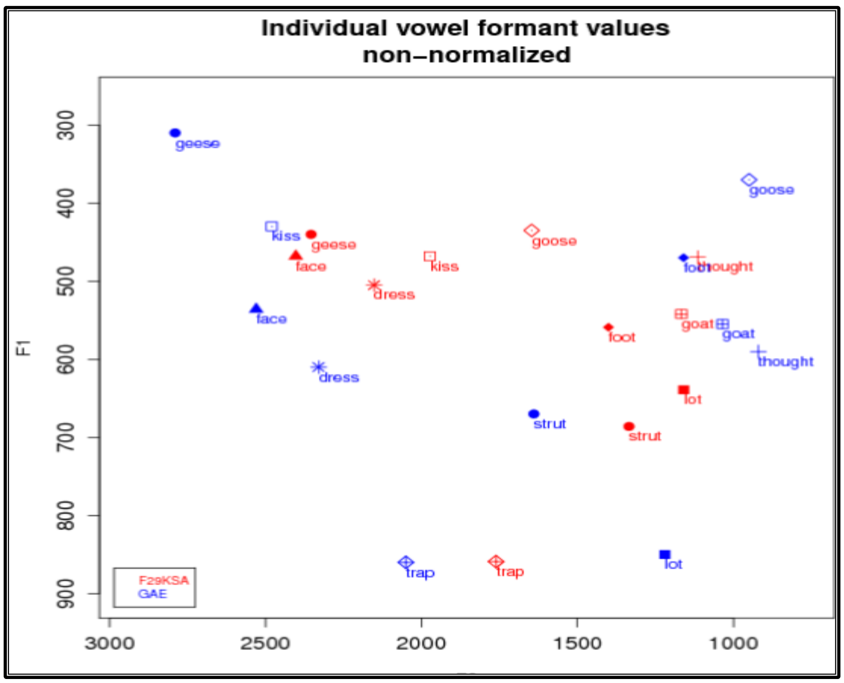
The completed Praat analysis yielded 11 spectrograms for each participant, who were coded with their country of origin (KSA), a gender letter M or F and a number (1-23) such as KSAF1 which stands for KSA, female, participant #1. All 7 correlates, F0, F1, F2, F3, F4, intensity and duration, were measured for each vowel and all 11 vowels. The value of each correlate was organized in tables by gender groups. The values were averaged for each speaker and across all participants.

To highlight the most salient features in vowel intelligibility, focus is given to measurements of F1, which is the vowel height and mouth aperture, and F2, which indicates tongue retraction thus showing if the vowel is fronted, centralized or backed. NORM (Kendall & Erik, 2010) is used to depict the first and second formants (F1 and F2) of a participant's vowel (Figure 1.4 below). These two formants are used in acoustic phonetics to describe the quality of vowels. Koffi (2019a, p. 91) describes this precisely when noting:

F1 and F2 are deemed the most relevant acoustic correlates for the study of vowels. F1 correlates with height, while F2 provides information about tongue advancement or retraction. Of the two, F1 correlates more strongly with intelligibility than F2 because it alone has 80% of the acoustic energy found in vowels (Ladefoged & Johnson, 2015, p. 207).

Figure 1.4

Comparative Vowel Space



As explained by Koffi (2019a, p. 95) "this vowel space depicts pictorially the similarities and differences when native speakers of American English, both males and females produce their vowels." Koffi (2019a) continues by confirming that it is also used for L2 English and shares the benefits from Ladefoged and Johnson (2015, p. 103):

> Vowel charts provide an excellent way of comparing different dialects of a language. This kind of plot arranges vowels in a similar way to the vowels in the IPA vowel chart.

> The format frequencies are spaced in accordance with the Bark scale, a measure of auditory similarity, so that the distance between any two sound reflects how far apart they sound. (p.95)

We have defined the benefits of using a vowel space for vowel comparisons and the most relevant correlates above. By defining boundaries of vowels and how we should compare them, this will greatly help our comparison of Saudi English and GAE vowels. To do so, we will replicate the methodology used by Backstrom (2018, pp. 28-29). First, by setting F1 and F2 boundaries for our vowel quadrant. Second, by precisely comparing Saudi English vowel features to GAE vowel features. Boundaries used by Backstrom (2018, p. 26) in her study of Minnesota vowels combined the numerical data for the Liljencrantz and Lindblom's (1972, p. 194) prototype vowel data for men (1972, p. 840) and women (2002, p. 194) with the vowel classification by Ladefoged and Johnson (2015, p. 46). She proposed the following classification tables (Table 1.5 and Table 1.6) for F1 and F2:

Table 1.5

F1 Boundaries for each Level of Vowel Height

	High	**Mid**	**Low**
F1 men	< 400	400 – 600	> 600
F1 women	< 480	480 – 720	> 720

Table 1.6

F2 Boundaries for each Region of Tongue Retraction

	Front	**Central**	**Back**
F2 men	≥ 1600	1200 – 1599	< 1200
F2 women	≥ 1920	1440 – 1919	< 1440

Continuing with Backstrom's method, we will now set the features used for our comparison of Saudi English vowels and GAE vowels. As we are focusing on comparing L2 English with GAE, some features will be prominently used to serve our purpose over others. The features used will be those of vowel height (F1) and tongue retraction (F2). Within those 2 features, we will qualify our comparisons by applying the "acceptable range of variance before a vowel becomes distinguished from other phonemic sounds and, [...] moves into a new type of vowel. Those ranges of variance are known as the *Just Noticeable Difference (JND)*" (Backstrom, 2018, p. 29). As seen previously (Table 1.5), vowel height (F1) will be described by using *high vowels, mid vowels, and low vowels* relative to their place within set boundaries. As for tongue retraction (F2), we will describe them as *front vowels, central vowels, and back vowels* (Table 1.6).

Conclusion

The analysis of vowel intelligibility of Saudi spoken English starts with a complete description of the characteristics for vowel height according to F1 data. It continues with a full description of the horizontal tongue movement according to F2 data. With F1 and F2 data presented, the distinctive features of SSE vowels will be highlighted. The third part of the analysis will assess the internal masking and intelligibility of the Saudi-accented English vowel inventory. Internal masking refers to the acoustic degree in which Saudi speakers can distinguish their own vowel inventory. Intelligibility assessments are derived from those results. The fourth part will compare SSE vowel production to GAE ones. Similarities will be highlighted and differences will be used to assess if they interfere with intelligibility. To do so, the fifth part will offer an external masking analysis and intelligibility assessment. External masking refers to how a vowel produced by Saudi speakers mask the adjacent vowel produced by GAE speakers.

The female participants analysis is given priority followed by their male counterparts. Pedagogical implications will be explored based on the results of this vowel intelligibility analysis. Additional insights will be provided as a concluding chapter in analyzing Saudi-accented English vowels.

Chapter II: Acoustic Measurements and Vowel Space of Female Speakers

Chapter Introduction

This chapter is devoted to the acoustic phonetic characteristics of female Saudi spoken English (SSE) with a complete intelligibility analysis. Female SSE vowel data for F1 and F2 are given along with a vowel space depiction and an intelligibility assessment as it relates to internal masking. Lastly, female SSE vowels are compared to female GAE ones. The comparisons, based on F1 and F2 formants, will highlight some key differences that lead to external masking and intelligibility issues.

The first three sections describe the characteristics of female SSE vowels for vowel height (F1), tongue movement (F2) and provide a comprehensive vowel space depiction. The fourth section evaluates their level of internal masking and intelligibility. The fifth section compares the features of female SSE vowels with those of female GAE for F1 and F2. The last section will focus on differences that cause poor intelligibility due to complete external masking as per the Acoustic Masking and Intelligibility (AMI) theory.

Vowel Height Analysis according to F1 Data

Vowel height is determined by F1. As Ladefoged & Johnson (2015, p. 221) describes "the frequency of the first formant certainly shows the relative vowel height quite accurately." The noticeable threshold for differences is 60 Hz for F1. The *trap* vowel [æ], the *thought* vowel [ɔ] and the *strut* vowel [ʌ] have standard deviations above 60 Hz. These vowels have noticeable height differences for female SSE. Table 2.1 below presents the vowel height measurements for 23 participants (F1).

Table 2.1

KSA Female F1 Measurements Table

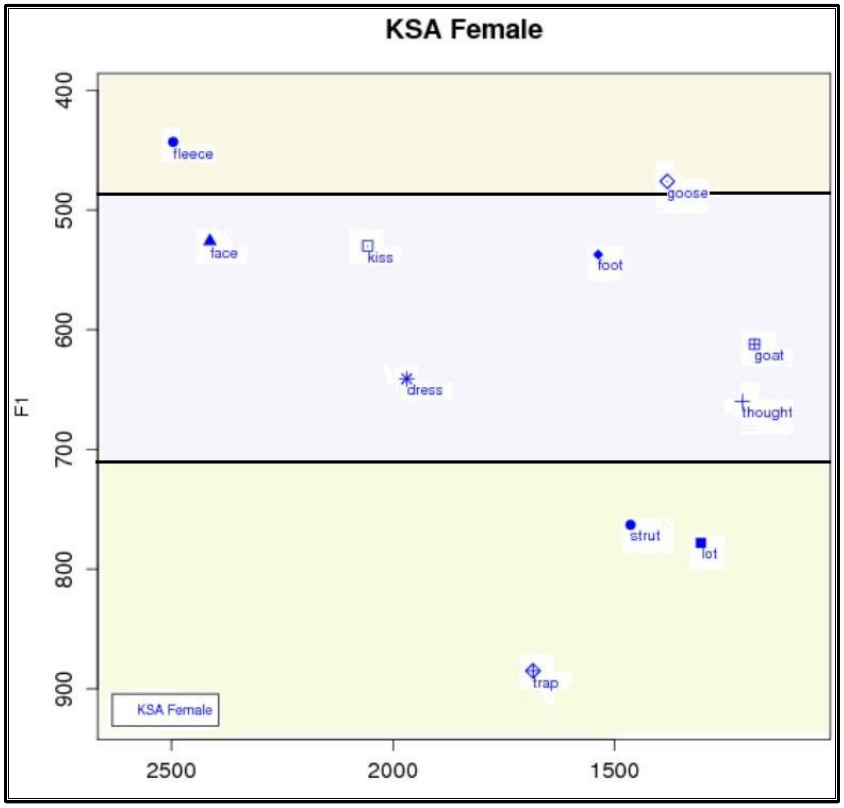
Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**foot**	**goose**	**strut**
F1 Correlate	**[i]**	**[ɪ]**	**[e]**[5]	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**[6]	**[ʊ]**	**[u]**	**[ʌ]**
KSAF1	423	480	504	551	866	739	552	560	532	431	731
KSAF2	389	480	516	637	1045	851	654	598	493	484	869
KSAF3	510	557	529	631	879	814	724	622	546	553	802
KSAF4	508	550	561	705	923	828	720	616	558	446	818
KSAF5	490	567	567	654	888	738	656	620	566	551	779
KSAF6	442	523	464	615	808	725	657	543	531	466	662
KSAF7	416	540	577	653	935	851	779	660	582	479	862
KSAF8	407	492	415	557	757	739	581	577	499	434	677
KSAF9	424	533	573	689	927	729	587	617	533	523	817
KSAF10	425	516	486	621	881	750	546	593	467	459	754
KSAF11	414	555	548	610	924	737	669	651	532	470	686
KSAF12	459	523	558	650	876	817	727	625	553	492	732
KSAF13	434	546	482	673	982	841	671	575	516	496	844
KSAF14	462	591	551	692	953	846	707	596	529	458	832
KSAF15	461	563	484	593	896	761	604	615	539	454	755
KSAF16	415	529	668	669	1004	815	644	594	716	451	803
KSAF17	417	551	544	698	930	788	650	596	494	475	800
KSAF18	468	501	505	657	812	725	670	612	509	457	707
KSAF19	466	503	503	567	865	790	739	641	544	440	724
KSAF20	446	523	457	601	611	755	660	706	525	457	743
KSAF21	420	529	477	651	854	723	668	569	542	466	694
KSAF22	424	518	590	645	860	710	571	555	496	525	678
KSAF23	478	518	546	714	882	816	741	738	554	476	789
Mean	**443**	**530**	**526**	**641**	**885**	**778**	**660**	**612**	**537**	**476**	**763**
St. Deviation	32.7	28.1	54.4	46.1	87.5	48.2	63.8	45.9	47.4	34.1	62.7
P&B[7] (1952)	**310**	**430**	**536**	**610**	**860**	**850**	**590**	**555**	**470**	**370**	**760**

On the F1 frequency for female participants, vowels are qualified as high vowels for heights under 480 Hz. They are classified as mid vowels for an F1 between 480 and 720 Hz. All F1 measurements above 720Hz are considered as low vowels (Table 1.7). The full characteristics of SSE female vowel height is presented below based on these thresholds. They produce most of their vowels as mid vowels (54%). They also have two high vowels and three low vowels, as shown in the vowel space Figure 2.1 below:

[5] data taken from Hillenbrand et al. (1995)
[6] data taken from Hillenbrand et al. (1995)
[7] stands for Peterson & Barney

Figure 2.1

Female SSE Vowel Height Levels



The *fleece* vowel [i] (443 Hz) is the highest vowel followed by the *goose* vowel [u] (476 Hz). The *goose* vowel [u] (476 Hz) is the lowest of the high vowels with only 4 Hz of distance from the mid vowel boundary of 480 Hz. The standard deviation is 34.1 Hz with seven participants producing it as a mid vowel and the rest of the participants producing it as a high vowel. High vowels appear to be the most stable with the lowest standard deviations in all vowel levels.

The mid vowels are the *face* vowel [e] (526 Hz), the *kiss* vowel [ɪ] (530 Hz), the *foot* vowel [ʊ] (537 Hz), the *goat* vowel [o] (612 Hz), the *dress* vowel [ɛ] (641 Hz) and the *thought* vowel [ɔ] (660 Hz). The vowels [ɪ] and [ʊ] which are ordinarily high vowels in GAE are produced as mid vowels in SSE. Here the *kiss* [ɪ] vowel is the most stable sound with the lowest standard deviation of all SSE vowels (28.1 Hz). Notably, five participants (21%) produce the *thought* vowel [ɔ] beyond the mid vowel boundary of 720 Hz as a low vowel.

The three low vowels are the *strut* vowel [ʌ] (763 Hz), the *lot* vowel [ɑ] (778 Hz) and the *trap* vowel [æ] (885 Hz). The *trap* vowel [æ] is the sound with the highest standard deviation of all SSE vowels at 87.5 Hz. This deviation far exceeds the JND threshold of 60 Hz for distinguishing between two different phonemes. This is specifically noteworthy as the acoustic spread between participant KSAF2 and KSAF20 is 434 Hz. The *trap* vowel [æ] for KSAF2 (611 Hz) is at mid vowel level while KSAF20 (1045 Hz) is at the lowest of all vowels. Consequently, SSE low vowels are the most unstable vowels produced with the highest standard deviation compared to other levels.

Horizontal Tongue Movement Analysis according to F2 Data

Table 2.2 below focuses on measurements pertaining to tongue advancement and retraction (F2). The Just Noticeable Difference threshold for F2 is 200 Hz. The data below shows that these female participants are 100% consistent between themselves for tongue movements. None of their standard deviations go beyond the JND threshold.

Table 2.2

KSA Female F2 Measurements Table

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**foot**	**goose**	**strut**
F2 Correlate	**[i]**	**[ɪ]**	**[e]**[8]	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**[9]	**[ʊ]**	**[u]**	**[ʌ]**
KSAF1	2594	2172	2451	1995	1510	1278	997	1106	1356	1339	1363
KSAF2	2533	2037	2454	1861	1676	1273	1076	1155	1529	1335	1369
KSAF3	2750	2064	2627	1955	1713	1344	1238	1245	1469	1381	1505
KSAF4	2259	2016	2579	1877	1657	1315	1141	1028	1418	1140	1416
KSAF5	2248	2085	2366	1937	1779	1293	1187	1165	1488	1492	1384
KSAF6	2304	1994	2386	1873	1587	1269	1312	1208	1449	1434	1443
KSAF7	2577	2357	2410	2142	1702	1236	1263	1065	1306	1157	1419
KSAF8	2322	1839	2205	1850	1599	1417	1141	1126	1574	1423	1408
KSAF9	2575	1884	2409	1931	1545	1206	941	1137	1608	1282	1415
KSAF10	2504	1986	2443	1940	1716	1193	962	1089	1454	1290	1386
KSAF11	2429	2084	2399	2027	1777	1153	1134	1172	1478	1287	1453
KSAF12	2637	2245	2452	2118	1839	1503	1415	1365	1728	1467	1657
KSAF13	2276	1910	2283	1940	1706	1227	1183	1219	1493	1444	1400
KSAF14	2505	1975	2522	2021	1644	1364	1305	1191	1775	1399	1569
KSAF15	2554	2093	2453	2080	1722	1362	1338	1288	1571	1556	1467
KSAF16	2348	2084	2331	1986	1795	1373	1307	1347	1944	1709	1575
KSAF17	2451	2197	2288	2060	1770	1284	1550	1060	1574	1365	1515
KSAF18	2592	2256	2525	1915	1743	1345	1241	1162	1457	1380	1577
KSAF19	2540	2060	2402	2005	1705	1341	1245	1155	1358	1212	1431
KSAF20	2651	2062	2535	2092	1641	1290	1131	1097	1429	1346	1454
KSAF21	2587	2030	2430	1909	1662	1366	1329	1220	1605	1327	1491
KSAF22	2639	1903	2187	1930	1613	1238	1111	1382	1737	1640	1402
KSAF23	2528	1979	2364	1843	1630	1348	1332	1251	1550	1351	1569
Mean	**2496**	**2057**	**2413**	**1969**	**1684**	**1305**	**1212**	**1184**	**1537**	**1381**	**1464**
St. Deviation	141.1	125.9	108.6	87.4	82.1	79.2	145.8	96.6	149.2	136.0	80.0
P&B (1952)	**2790**	**2480**	**2530**	**2330**	**2050**	**1220**	**920**	**1035**	**1160**	**950**	**1400**

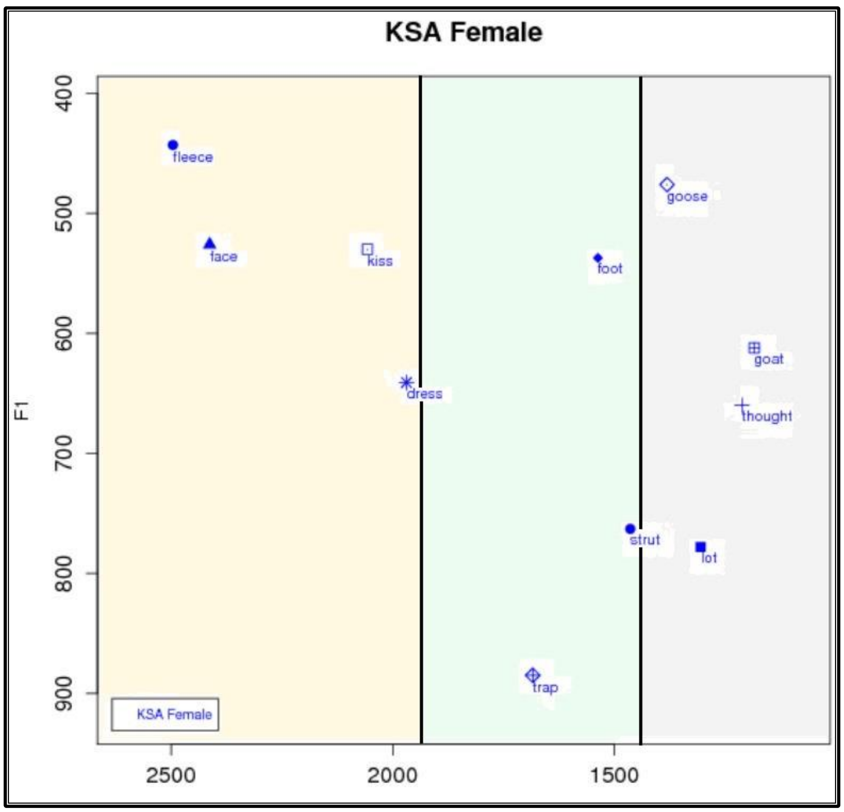
For the female F2 frequency, vowels are deemed as front vowels in the region above 1920 Hz. They are qualified as central vowels if their F2 ranges between 1440 Hz and 1919 Hz.

[8] data taken from Hillenbrand et al. (1995)
[9] data taken from Hillenbrand et al. (1995)

Any vowels with a value under 1440Hz are considered back vowels (Table 1.8). Female SSE is characterized by tongue movement for all three regions. According to these thresholds, these participants use equally the front and back regions for vowels with four, respectively. Only three vowels are central to their speech as seen below (Figure 2.2).

Figure 2.2

Female SSE Vowel Tongue Regions



The *fleece* vowel [i] (2496 Hz), the *face* vowel [e] (2413 Hz), the *kiss* vowel [ɪ] (2057 Hz) and the *dress* vowel [ɛ] (1969 Hz) are fronted vowels. The most fronted vowel is the *fleece* vowel [i] with a standard deviation of 141.1 Hz. Participant KSAF5 produces such vowel at 2248 Hz while KSAF3 is extremely fronted at 2750 Hz with an acoustic distance of 502 Hz separating them. The *dress* vowel [ɛ] is the most stable fronted vowel at a standard deviation of 87.4 Hz;

however, its vowel frequency (1969 Hz) is very close to the boundary (1920 Hz) separating the front and central region.

The *trap* vowel [æ] (1684 Hz), the *foot* vowel [ʊ] (1537 Hz) and the *strut* vowel [ʌ] (1464 Hz) are central vowels. The *foot* vowel [ʊ] is the most unstable with the highest standard deviation (149.2 Hz) of all vowels. Participant KSAF7 produces such vowel (1306 Hz) in the back region while KSAF16 makes it a fronted vowel (1944 Hz). The acoustic distance between these two participants is 638 Hz for their *foot* vowel [ʊ]. Lastly, the *strut* vowel [ʌ] is also unstable as a central vowel with almost half of the participants (47%) producing it as a back region vowel. With a deviation of only 80 Hz, the *strut* vowel [ʌ] (1464 Hz) is the most stable one for that region; however, it is very near to the back region boundary of 1440 Hz.

The back vowels are the *goose* vowel [u] (1381 Hz), the *lot* vowel [ɑ] (1305 Hz), the *thought* vowel [ɔ] (1212 Hz) and the *goat* vowel [o] (1184 Hz) in that region. The most stable vowel produced is the *lot* sound [ɑ] with the lowest standard deviation for all regions at 79.2 Hz. The *thought* vowel [ɔ] has the highest deviation (145.8 Hz) for back vowels. Participant KSAF9 produces the *thought* vowel at a frequency of 941 Hz while KSAF17 has the highest frequency (1550 Hz) realizing this vowel in the central region with an acoustic distance of 609 Hz between them.

Summary Observations. The acoustic vowel space for female Saudi spoken English highlights the following singularities. The *fleece* vowel [i] and the *goose* vowel [u] are the only high vowels in the speech of 23 participants. They produce the *kiss* vowel [ɪ] and the *foot* vowel [ʊ] as mid vowels on par with the *face* vowel [e], the *dress* vowel [ɛ], the *thought* vowel [ɔ] and the *goat* vowel [o]. The *strut* vowel [ʌ], *trap* vowel [æ], and the *lot* vowel [ɑ] are produced as low vowels.

Internal Masking and Intelligibility

The assessment of the severity of intelligibility combines masking measurements in F1 and RFL calculations (appendix B). For the focus of this study, vowels with complete masking will be highlighted. The complete masking threshold is an acoustic distance of < 20 Hz between two different phonemes. The vowels that Saudi female participants in the study have a hard time differentiating and which can cause intelligibility issues are summarized in Table 2.3 below. For female SSE, only two vowels present complete internal masking.

Table 2.3

Internal Masking and Intelligibility of Female SSE Vowels

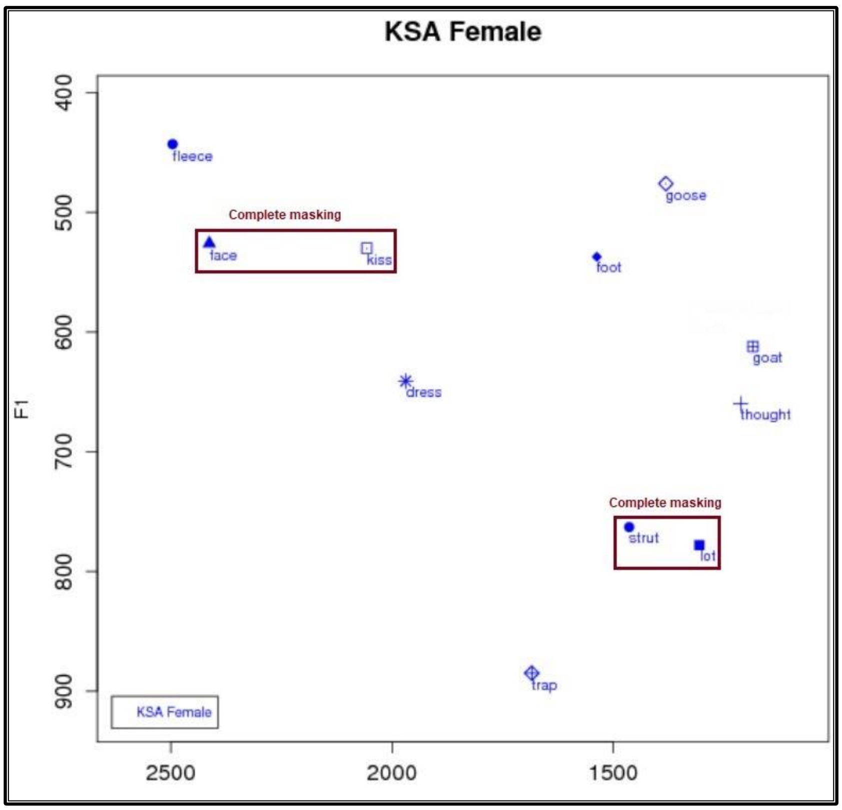
Vowel Pairs	**F1 Distance**	**Internal Masking Levels**		**RFL**		**Intelligibility Rating**
[i] vs. [ɪ]	87 Hz	No masking		95%		Good intelligibility
[ɪ] vs. [e]	**4 Hz**	**Complete masking**		**80%**		**Poor intelligibility**
[e] vs. [ɛ]	114 Hz	No masking		53%		Good intelligibility
[ɛ] vs. [æ]	245 Hz	No masking		53%		Good intelligibility
[u] vs. [ʊ]	61 Hz	No masking		7%		Good intelligibility
[ʊ] vs. [o]	75 Hz	No masking		12%		Good intelligibility
[o] vs. [ɔ]	48 Hz	Slight masking		88%		Average intelligibility
[ɔ] vs. [ɑ]	118 Hz	No masking		26%		Good intelligibility
[æ] vs. [ʌ]	122 Hz	No masking		68%		Good intelligibility
[ʌ] vs. [ɑ]	**14 Hz**	**Complete masking**		**65%**		**Average intelligibility**
[æ] vs. [ɑ]	107 Hz	No masking		76%		Good intelligibility

The first complete internal masking is a fronted vowel. The acoustic distance between the *kiss* vowel [ɪ] (530 Hz) and the *face* vowel [e] (526 Hz) is only 4Hz which indicates a complete masking. With an RFL at 80%, the intelligibility is deemed poor. As an example, when a Saudi female speaker of English says <disk> and <desk>, no difference would be audible

The second complete masking is present for one of the low vowel pairs. The *strut* vowel [ʌ] (763 Hz) and the *lot* vowel [ɑ] (778 Hz) are only separated by an acoustic distance of 14 Hz. With an RFL of 65%, this could lead to poor intelligibility depending on the speaker. Distinguishing between <duck> and <dock> may be more difficult. These two intelligibility issues are shown in Figure 2.3 below:

Figure 2.3

Internal Maskings for Female SSE Vowels



Overall, the intelligibility of female SSE vowels as it pertains to internal masking is very robust. They can distinguish most (81%) of their vowels with no consequence to intelligibility. Eight of their 11 vowels are completely distinguishable from each other with more than 60 Hz of distance between them. Only the *kiss* vowel [ɪ] leads to poor intelligibility because of a complete masking with the *face* vowel [e] and an associated RFL of 80%. The *strut* vowel [ʌ] causes intelligibility to be average.

Comparison: Female SSE and Female GAE

In this section, Saudi speaker's vowels are compared and contrasted with those produced by GAE speakers. For F1, female SSE has 6 noticeable acoustic differences with female GAE. The *fleece* [i], *kiss* [ɪ] and *goose* [u] vowels has the highest differences. For F2, 63% of female participants differed from their American counterparts. The *goose* vowel [u] tongue movement frequency is moved forward by 431 Hz compared to the GAE position. Table 2.4 lists the vowels from both group of speakers.

Table 2.4

F1 and F2 Data for Female SSE and GAE vowels

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**foot**	**goose**	**strut**
Vowel	**[i]**	**[ɪ]**	**[e]**[10]	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**[11]	**[ʊ]**	**[u]**	**[ʌ]**
F1											
Female SSE	443	530	526	641	885	778	660	612	537	476	763
Female GAE	310	430	536	610	860	850	590	555	470	370	760
F1 difference	**133**	**100**	10	31	25	**72**	**70**	57	**67**	**106**	3
F2											
Female SSE	2496	2057	2413	1969	1684	1305	1212	1184	1537	1381	1464
Female GAE	2790	2480	2530	2330	2050	1220	920	1035	1160	950	1400
F2 difference	**294**	**423**	117	**361**	**366**	85	**292**	149	**377**	**431**	64

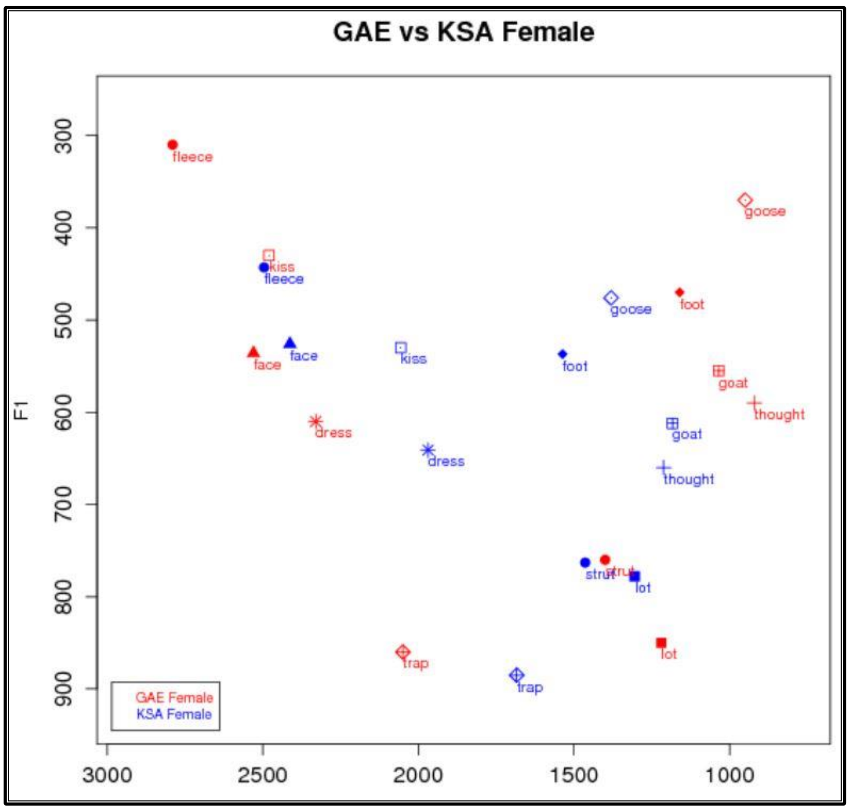
Both SSE and GAE produce the *fleece* vowel [i] (SSE: 443 Hz; GAE: 310 Hz) as a high fronted phoneme. This high vowel produced by GAE speakers (310 Hz); however, is higher by 133 Hz compared with its counterpart (443 Hz) produced by Saudi speakers. The *trap* vowel [æ]

[10] Hillenbrand et al. (1995)
[11] Hillenbrand et al. (1995)

is the lowest sound for both groups. The *trap* vowel of SSE (885 Hz) is very close to the GAE (860 Hz) as a low central sound with only 25 Hz of difference between them. For both SSE and GAE, the *goose* vowel [u] is a high backed sound. This vowel produced by GAE speakers (370 Hz) is higher by 106 Hz compared to the SSE sound (476 Hz). To give a clearer comparison of all remaining vowels, an acoustic vowel space is provided in Figure 2.4.

Figure 2.4

Comparative Vowel Space for Female SSE and Female GAE



More similarities between female Saudi-accented English and female GAE vowels are found in all three regions (front, central & back) and account for 81% of the total space. The *face* vowel [e] and *dress* vowel [ɛ] are both fronted mid vowels. The *trap* [æ], *strut* [ʌ] and *lot* [ɑ] vowels are low for both SSE and GAE. The *goat* [o] and *thought* [ɔ] vowels are similarly mid backed vowels.

The differences are most noticeable for two vowels only. The *kiss* vowel [ɪ] in SSE is lowered to a mid fronted position while its GAE counterpart is much higher as a fronted high sound. The SSE *foot* vowel [ʊ] is lowered to a mid central vowel while the GAE *foot* sound [ʊ] is a high backed vowel.

External Masking and Intelligibility

External masking calculates the acoustic distance between vowels produced by Saudi speakers and those produced by GAE speakers. When the acoustic distance between two different phonemes are less than 20 Hz, they are considered to have a complete external masking. Such maskings are visible below in Table 2.5.

Table 2.5

External Masking and Intelligibility of Female SSE and Female GAE

Vowel Pairs	F1 Distance	External Masking Levels		RFL		Intelligibility Rating
[i] vs. [ɪ]	**13 Hz**	**Complete masking**		**95%**		**Poor intelligibility**
[ɪ] vs. [e]	**6 Hz**	**Complete masking**		**80%**		**Poor intelligibility**
[e] vs. [ɛ]	84 Hz	No masking		53%		Good intelligibility
[ɛ] vs. [æ]	219 Hz	No masking		53%		Good intelligibility
[u] vs. [ʊ]	**6 Hz**	**Complete masking**		**7%**		**Good intelligibility**
[ʊ] vs. [o]	**18 Hz**	**Complete masking**		**12%**		**Good intelligibility**
[o] vs. [ɔ]	22 Hz	Moderate masking		88%		Poor intelligibility
[ɔ] vs. [ɑ]	190 Hz	No masking		26%		Good intelligibility
[æ] vs. [ʌ]	125 Hz	No masking		68%		Good intelligibility
[ʌ] vs. [ɑ]	87 Hz	No masking		65%		Good intelligibility
[æ] vs. [ɑ]	35 Hz	Moderate masking		76%		Average intelligibility

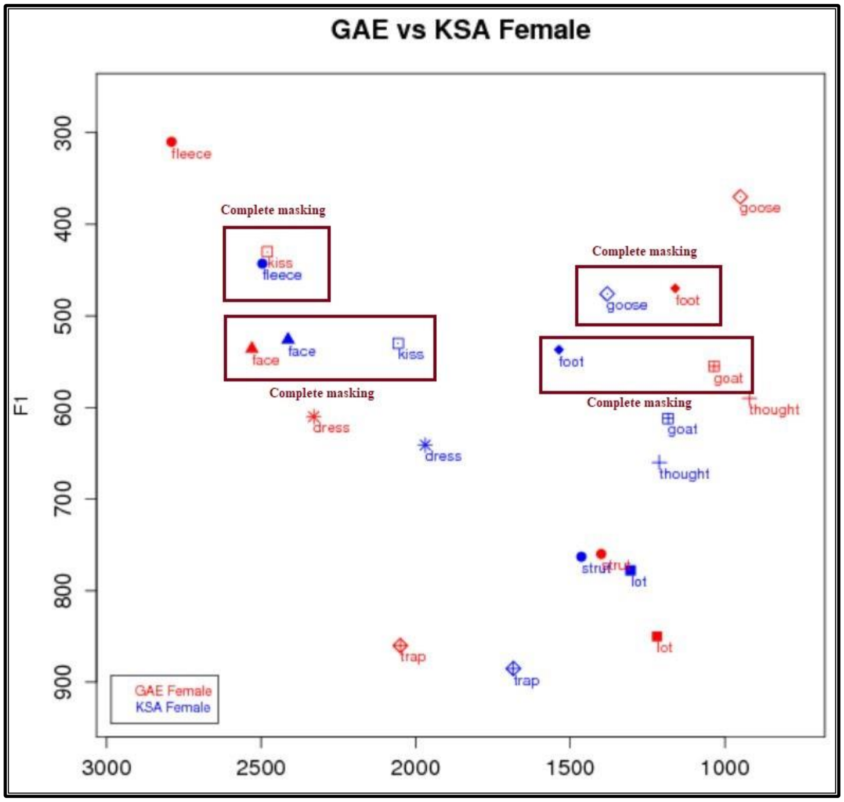
Focus is given to complete external masking findings with RFLs that cause poor intelligibility. For female SSE, only two sets of vowels are problematic for GAE hearers. The first set is the *fleece* [i] and *kiss* [ɪ] vowels. The second set is the *goose* [u] and *foot* [ʊ] vowels.

For the fronted vowels, female SSE measurements show two instances of complete masking. When female Saudi speakers produce the *fleece* sound [i] (443 Hz), it masks the GAE *kiss* sound [ɪ] (430 Hz) completely because the acoustic distance is only 13 Hz. With an RFL at 95%, this makes it completely unintelligible. For example, if a Saudi speaker says <seat>, it will be misperceived as <sit> by a GAE hearer. The second instance of complete masking occurs with the SSE *kiss* vowel [ɪ] (530 Hz) completely masking the GAE *face* vowel [e]. The distance separating them is only 6 Hz and with an RFL at 80%, makes it difficult to be distinguished. Although a Saudi speaker says <disk>, it is heard as <desk> by the GAE hearer.

For back vowels, the *goose* vowel [u] (476 Hz) produced by Saudi speakers mask the *foot* vowel [ʊ] (470 Hz) in GAE. The acoustic distance between them is 6 Hz with the RFL very low at 7%, resulting in masking that is unlikely to cause intelligibility problems. Instances where a Saudi speaker says the word <pool> might be heard by GAEs as <pull>. Complete masking also occurs between the *foot* vowel [ʊ] (537 Hz) in SSE and the *goat* vowel [o] (555 Hz) in GAE. Distance of only 18 Hz between the two sounds means a complete masking; however, the low RFL of 12% would not yield intelligibility issues. In rare cases of isolated utterances, if a female Saudi speaker says <pull> could be heard as <poll> by GAE counterparts. Figure 2.5 shows such complete external maskings along with the other vowels.

Figure 2.5

External Maskings for Female SSE and GAE vowels



Overall, the intelligibility of female SSE as it relates to external masking is robust. Only two out of eleven vowels (18%) cause severe problems in female Saudi-accented speech. The *fleece* vowel [i] in SSE can be confused with the *kiss* vowel [ɪ] for GAE. Also, the *kiss* vowel [ɪ] in SSE can be misperceived as the *face* vowel [e] by female GAE hearers. Both vowels cause poor intelligibility. Although female SSE show external maskings for the *goose* vowel [u] and *foot* vowel [ʊ], they do not affect intelligibility enough to be considered. With four external maskings present, only the high vowels [i] and [ɪ] in female SSE lead to poor intelligibility with RFLs at 95% and 80% respectively.

Conclusion

The vowel space of female Saudi-accented English contains two high vowels (fronted [i] and backed [u]), six mid vowels (fronted [e], [ɪ], [ɛ] and backed [ʊ], [o], [ɔ]) and three low vowels (central [æ], [ʌ] and backed [ɑ]). Their vowels are distinguishable at 81% when they speak and only two vowels cause intelligibility issues. The *kiss* vowel [ɪ] causes poor intelligibility with the *face* vowel [e]. This is due to an internal masking with only 4 Hz of acoustic distance between the two sounds and an RFL of 80%. The *strut* vowel [ʌ] causes average intelligibility with the *lot* vowel [ɑ]. An acoustic distance of only 14 Hz separates the two sounds; however, the RFL of 65% only impacts intelligibility in certain conditions.

When comparing the vowel spaces of female SSE to female GAE, similarities account for 81% between them. Only two vowels distinguish the Saudi inventory from their American counterparts. First, the *kiss* vowel [ɪ] is fronted for both groups; however, female SSE produce it as a mid vowel. Female GAE speakers produce it as a high vowel. Secondly, the *foot* vowel [ʊ] is a mid central sound for female SSE while a high backed sound for female GAE. These differences lead to an interference with intelligibility. A poor intelligibility results from the first difference with the *kiss* vowel [ɪ]. This also has an impact on the intelligibility of the SSE *fleece* vowel [i]. With RFLs at 80% and 95% respectively, intelligibility is poor when interacting with female Americans. The second difference with the *foot* vowel [ʊ] does not impact intelligibility because of the lower RFL factor.

Chapter III: Acoustic Measurements and Vowel Space of Male Speakers

Chapter Introduction

This third chapter focuses on the F1 and F2 of vowels produced by male speakers. It assesses the intelligibility of their vowels and contrasts them with vowels produced by GAE speakers. As in the previous chapter, the AMI theory will be used to determine intelligibility levels. The number of male participants is smaller relative to female participants. Although male speakers of English are present in Higher Education, their willingness to participate in research focused on their phonetic characteristics was surprisingly low. Nevertheless, Koffi (2020, p. 4) highlighted Ladefoged's perspective on participant numbers as "a minimum of six speakers are recommended for most acoustic phonetic studies." A total of nine male participants contributed to this study.

The characteristics of male SSE vowels for F1, F2 will be presented in the first three sections along with a vowel space chart. The fourth section will focus on internal masking and intelligibility ratings. The fifth section will compare SSE vowels to those of GAE. The final section will cover the external masking findings and intelligibility consequences.

Vowel Height Analysis according to F1 Data

The following measurements have been collected from nine participants for F1. The *goose* vowel [u], the *kiss* vowel [ɪ] and the *lot* vowel [ɑ] in male SSE have standard deviations above 60 Hz. These vowels are not produced at the same heights for all participants. The findings for vowel height (F1) in male Saudi-accented English are presented below in Table 3.1.

Table 3.1

KSA Male F1 Measurements Table

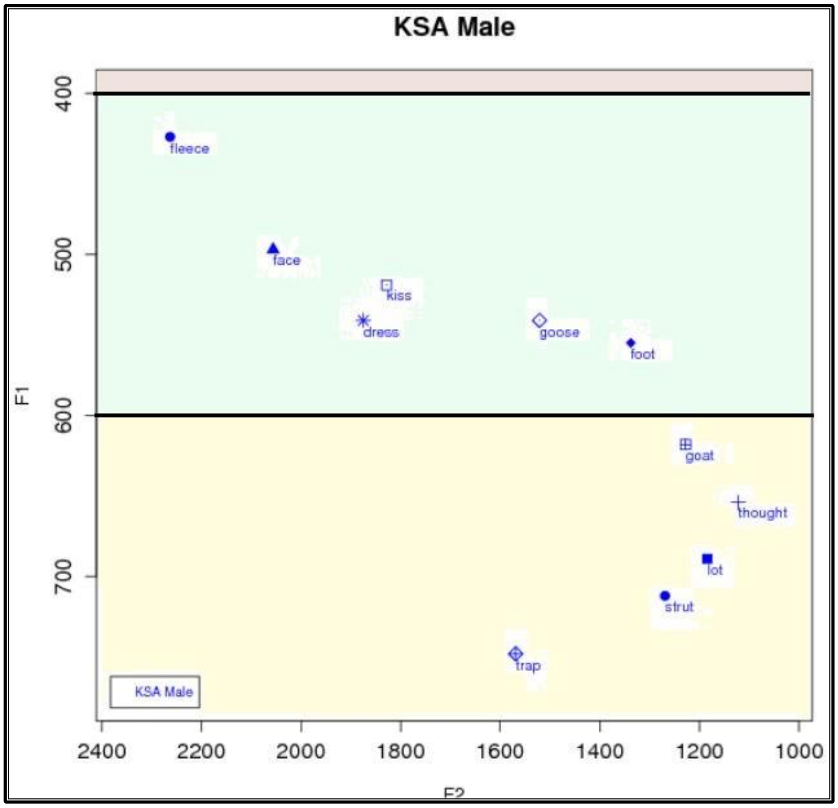
Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**foot**	**goose**	**strut**
F1 Correlate	**[i]**	**[ɪ]**	**[e]**[12]	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**[13]	**[ʊ]**	**[u]**	**[ʌ]**
KSAM1	396	620	502	551	702	646	642	588	541	493	712
KSAM2	430	526	483	558	812	742	670	652	507	459	691
KSAM3	392	481	472	536	712	691	661	634	574	526	674
KSAM4	453	484	441	447	711	574	538	535	494	490	656
KSAM5	489	468	491	566	720	715	646	534	519	461	668
KSAM6	487	502	572	597	817	804	707	668	665	558	808
KSAM7	427	673	546	538	793	703	705	677	595	719	788
KSAM8	354	463	478	554	736	667	622	598	540	478	734
KSAM9	415	451	486	526	731	658	692	673	558	681	677
Mean	**427**	**519**	**497**	**541**	**748**	**689**	**654**	**618**	**555**	**541**	**712**
St. Deviation	44.4	76.9	39.6	40.9	45.9	64.6	52.3	56.6	52.2	96.0	54.4
P&B (1952)	**270**	**390**	**476**	**530**	**660**	**730**	**570**	**497**	**440**	**300**	**640**

On the F1 frequency for males, vowels are classified as high vowels for heights under 400 Hz. They are classified as mid vowels for an F1 range between 400 and 600 Hz. All F1 measurements above 600Hz are considered as low vowels (Table 1.7). Male Saudis produce vowels in only two levels of aperture: six mid vowels and five low vowels. They do not produce any high vowels. The full characteristics of SSE male vowel height shown in the vowel space Figure 3.1 below:

[12] from Hillenbrand et al. (1995)
[13] from Hillenbrand et al. (1995)

Figure 3.1

Male SSE Vowel Height Levels



The mid vowels are the *fleece* vowel [i] (427 Hz), the *face* vowel [e] (497 Hz), the *kiss* vowel [ɪ] (519 Hz), the *dress* vowel [ɛ] (541 Hz), the *goose* vowel [u] (541 Hz) and the *foot* vowel [ʊ] (555 Hz). The vowels [i], [ɪ] and [u] which are high vowels in GAE are lowered to mid vowels in SSE. The *goose* vowel [u] is significantly lowered. It is separated by a distance of 241 Hz from its GAE equivalent (300 Hz). It is also the most inconsistent vowel produced in the mid level for Saudi male speakers with a standard deviation of 96 Hz. Notably, two participants produce the *goose* vowel [u] as a low vowel below 600 Hz. The *face* vowel [e] (497 Hz) is the most stable sound with only 39.6 Hz of deviation.

The four low vowels are the *goat* vowel [o] (618 Hz), the *thought* vowel [ɔ] (654 Hz), the *lot* vowel [ɑ] (689 Hz), the *strut* vowel [ʌ] (712 Hz) and the *trap* vowel [æ] (748 Hz). The vowel [o] which is classified as a mid vowel for male GAE is lowered for SSE by an acoustic distance of 121 Hz. The most stable low vowel for SSE is the *trap* vowel [æ] with a standard deviation of 45.9 Hz.

Horizontal Tongue Movement Analysis according the F2 Data

Male SSE tongue advancement and retraction measurements (F2) are given below in Table 3.2. As per the JND threshold of F2, any deviation of more than 200 Hz shows a noticeable difference in tongue movement between participants. Only the *goose* vowel [u] shows an inconsistency in production. The standard deviation is twice the JND threshold.

Table 3.2

KSA Male F2 Measurements Table

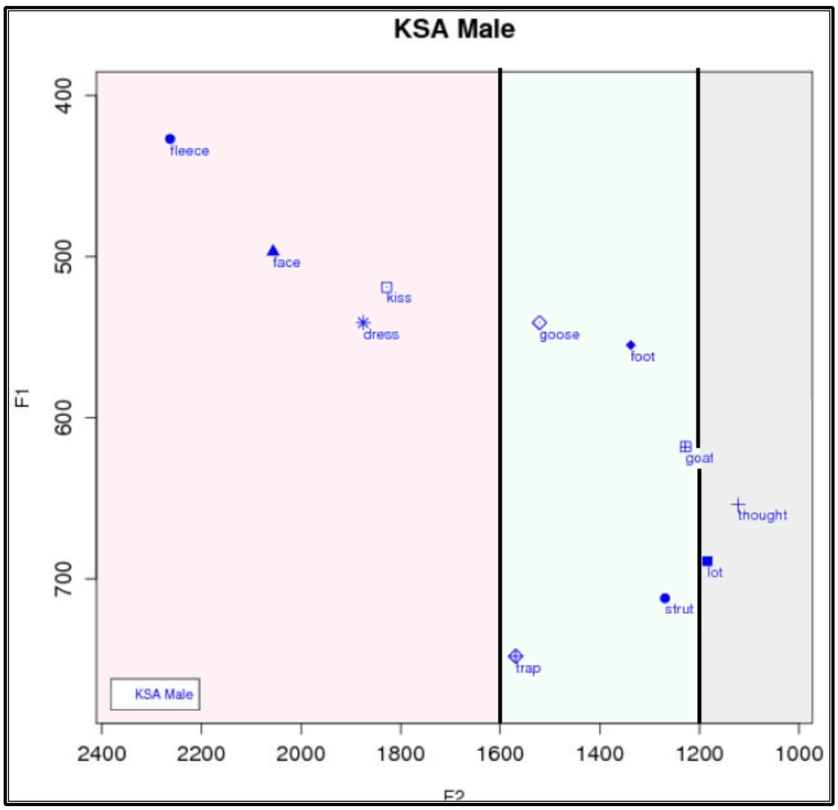
Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**foot**	**goose**	**strut**
F2 Correlate	**[i]**	**[ɪ]**	**[e]**[14]	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**[15]	**[ʊ]**	**[u]**	**[ʌ]**
KSAM1	2124	1764	1991	1741	1489	1137	1111	1355	1110	925	1263
KSAM2	2172	1775	2147	1825	1590	1158	1104	1227	1473	1337	1293
KSAM3	2409	1834	2073	1809	1648	1241	1190	1078	1222	1282	1309
KSAM4	2144	1802	2134	2059	1689	1244	1189	1348	1425	1712	1287
KSAM5	2460	1734	2216	2123	1555	1192	1142	1193	1464	1385	1197
KSAM6	2212	1747	1821	1880	1502	1240	1103	1161	1076	1200	1258
KSAM7	2125	1883	1910	1744	1427	1169	1069	1409	1460	1831	1196
KSAM8	2423	2035	2235	1841	1652	1114	999	1093	1246	1703	1337
KSAM9	2299	1881	1974	1850	1568	1160	1188	1192	1563	2317	1277
Mean	**2263**	**1828**	**2056**	**1875**	**1569**	**1184**	**1122**	**1228**	**1338**	**1521**	**1269**
St. Deviation	137.1	94.7	141.3	131.9	86.0	48.3	63.8	117.8	176.7	413.4	47.2
P&B (1952)	**2290**	**1990**	**2089**	**1840**	**1720**	**1090**	**840**	**910**	**1020**	**870**	**1190**

[14] from Hillenbrand et al. (1995)
[15] from Hillenbrand et al. (1995)

For the male F2 frequency, vowels are considered as front vowels in the region above 1600 Hz. They are classified as central vowels if their F2 ranges between 1200 Hz and 1599 Hz. Any vowels with a value under 1200 Hz are considered back vowels (Table 1.8). According to these thresholds, 45% of the vowels produced by the participants qualify as central vowels. Four vowels are fronted and only two are backed vowels as depicted in Figure 3.2.

Figure 3.2

Male SSE Vowel Tongue Regions



The fronted vowels in SSE for males are the *fleece* vowel [i] (2263 Hz), the *face* vowel [e] (2056 HZ), the *dress* vowel [ɛ] (1875 Hz) and the *kiss* vowel [ɪ] (1828 Hz). Similar to their GAE counterparts, the [i] vowel is the most fronted from their production. The most stable vowel in this region is the *kiss* vowel [ɪ] with a standard deviation of 94.7 Hz.

The *trap* vowel [æ] (1569 Hz), *goose* vowel [u] (1521 Hz), *foot* vowel [ʊ] (1338 Hz), *strut* vowel [ʌ] (1269 Hz) and *goat* vowel [o] (1228 Hz) are central vowels. Unlike male GAE who produce their vowels outside the central region, most of the SSE vowels are produced in that area. The vowel [ʌ] is the most stable with a deviation of only 47.2 Hz. The *goose* vowel [u] is the most peculiar of this region. In male GAE speakers, the *goose* vowel [u] is a back vowel. The acoustic distance between the SSE *goose* (1521 Hz) and GAE *goose* (870 Hz) is 651 Hz. These participants produce the *goose* vowel [u] as a central vowel. Furthermore, 44% of the participants make it a fronted vowel. It has the highest standard deviation at 413.4 Hz.

The backed vowels are the *lot* vowel [ɑ] (1184 Hz) and the *thought* vowel [ɔ] (1122 Hz). This region is also an important characteristic of male SSE as their GAE counterparts produce six vowels in this region.

Summary Observations. The measurements for F1 and F2 of male SSE brings to light the following features. These Saudi participants do not produce any high vowels. *Fleece* [i], *kiss* [ɪ] and *goose* [u] are mid vowels for these 9 participants. The *goose* [u] sound is also a central vowel making it a mid central vowel. The *goat* vowel [o] is a low vowel. The majority of male SSE vowels are central and they have only two back vowels, *lot* vowel [ɑ] and *thought* vowel [ɔ].

Internal Masking and Intelligibility

Internal masking and intelligibility ratings for male SSE vowels are displayed below in Table 3.3. Only one vowel presents a complete masking where F1 is less than 20 Hz. The *goose* vowel [u] and the *foot* vowel [ʊ] show a complete internal masking. These vowels are mid central in the vowel space of these participants. With a distance of 14 Hz, this complete masking does not impede intelligibility as the RFL is only 7%.

Table 3.3

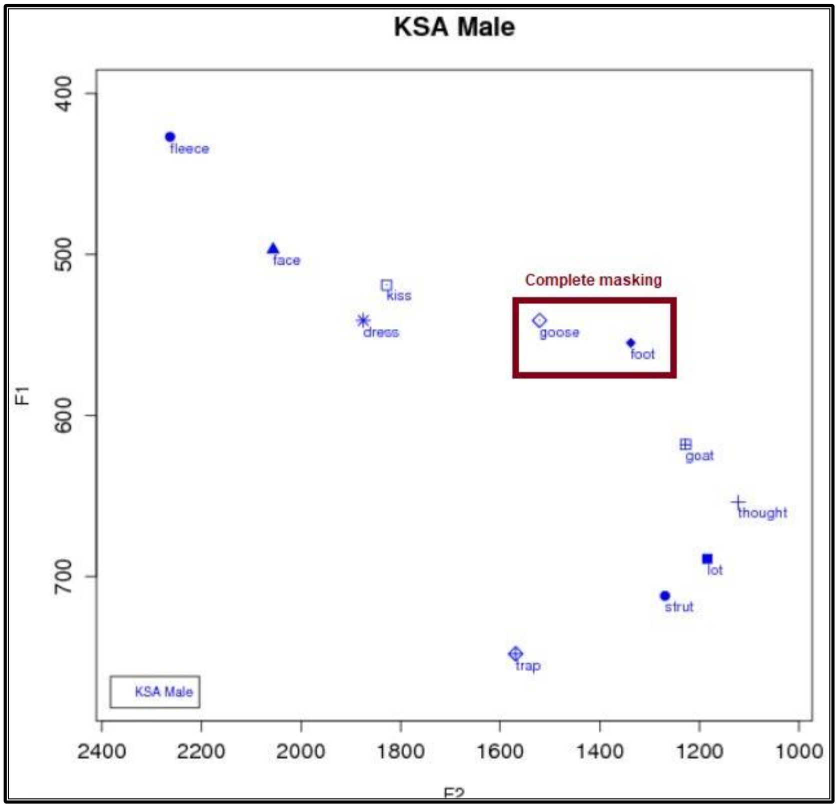
Internal Masking and Intelligibility of Male SSE Vowels

Vowel Pairs	F1 Distance	Internal Masking Levels		RFL		Intelligibility Rating
[i] vs. [ɪ]	92 Hz	No masking		95%		Good intelligibility
[ɪ] vs. [e]	22 Hz	Moderate masking		80%		Poor intelligibility
[e] vs. [ɛ]	45 Hz	Slight masking		53%		Good intelligibility
[ɛ] vs. [æ]	207 Hz	No masking		53%		Good intelligibility
[u] vs. [ʊ]	**14 Hz**	**Complete masking**		**7%**		**Good intelligibility**
[ʊ] vs. [o]	63 Hz	No masking		12%		Good intelligibility
[o] vs. [ɔ]	36 Hz	Moderate masking		88%		Poor intelligibility
[ɔ] vs. [ɑ]	35 Hz	Moderate masking		26%		Good intelligibility
[æ] vs. [ʌ]	36 Hz	Moderate masking		68%		Average intelligibility
[ʌ] vs. [ɑ]	23 Hz	Moderate masking		65%		Average intelligibility
[æ] vs. [ɑ]	59 Hz	Slight masking		76%		Good intelligibility

Most of the internal masking levels for SSE are moderate with 5 out of eleven vowels above the complete masking threshold. The *kiss* vowel [ɪ] shows a moderate masking with the *face* vowel [e]. At an RFL of 80%, this might cause intelligibility issues in other Saudi speaker speech. Similarly, the *goat* vowel [o] shows a moderate masking with the *thought* vowel [ɔ]. Because of the high RFL (88%) between them, this might be an issue for other speakers. All other moderate masking have lower RFL factors that would not cause immediate intelligibility issues. These participants present many singularities as it relates to the position of their vowels compared to GAE vowels. However, they have distinctive distances between all their vowels as seen below in Figure 3.3.

Figure 3.3

Internal Masking for Male SSE vowels



Overall, the intelligibility of male SSE vowels as it relates to their own speech production is very robust. None of their vowels show a poor intelligibility rating. Only the *goose* vowel [u] shows a complete masking with the *foot* vowel [ʊ]. However, the low RFL of 7% shows no impact to intelligibility. This unique vowel space will now be compared to GAE.

Comparison: Male SSE and Male GAE

A comparison of the characteristics of Saudi male vowels to the vowels of GAE is given in this section. For F1, male SSE presents eight differences with GAE values. The *goose* vowel [u] (541 Hz) has an acoustic distance that is almost two times lower than GAE (300 Hz). For F2 values, 36% of SSE tongue placements are different compared to GAE. The *goose* vowel [u]

(1521 Hz) has an acoustic difference of 651 Hz with GAE *goose* vowel (870 Hz). Table 3.4 summarizes the features of F1 and F2 for both groups.

Table 3.4

F1 and F2 Data for Male SSE and GAE vowels

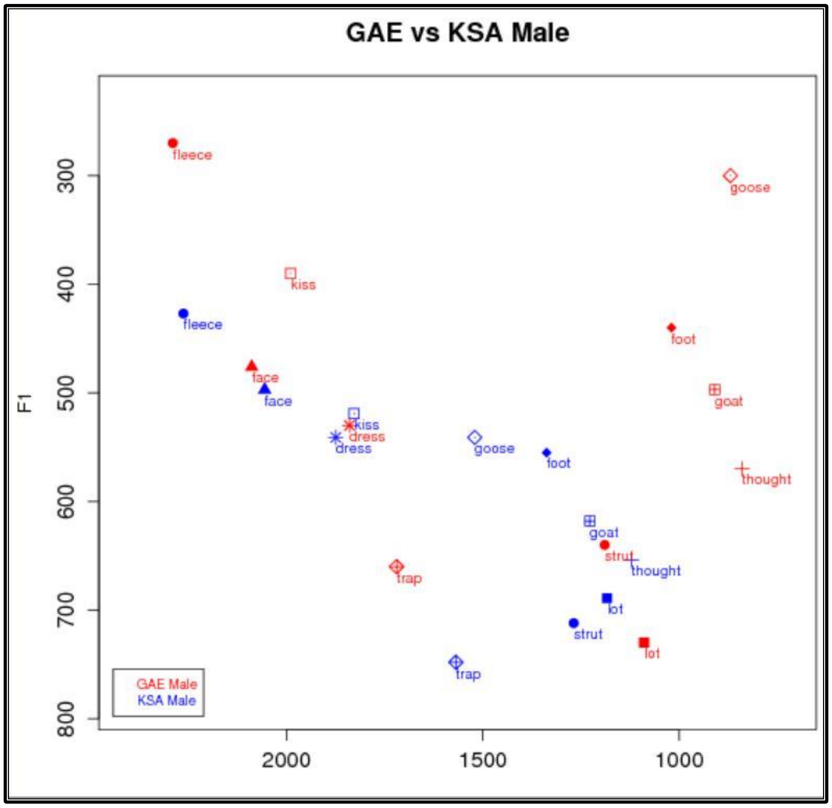
Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**foot**	**goose**	**strut**
Vowel	**[i]**	**[ɪ]**	**[e]**[16]	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**[17]	**[ʊ]**	**[u]**	**[ʌ]**
F1											
Male SSE	427	519	497	541	748	689	654	618	555	541	712
Male GAE	270	390	476	530	660	730	570	497	440	300	640
F1 difference	**157**	**129**	21	11	**88**	41	**84**	**121**	**115**	**241**	**72**
F2											
Male SSE	2263	1828	2056	1875	1569	1184	1122	1228	1338	1521	1269
Male GAE	2290	1990	2089	1840	1720	1090	840	910	1020	870	1190
F2 difference	27	162	33	35	151	94	**282**	**318**	**318**	**651**	79

Both male groups, SSE and GAE, have the *fleece* vowel [i] as the most fronted phoneme. Saudi-accented English's *fleece* (427 Hz) is lowered to a mid vowel by 157 Hz compared to the high GAE *fleece* (270 Hz). The *trap* vowel [æ] are both the lowest vowels for SSE (748 Hz) and GAE (660 Hz). The *goose* vowel [u] in GAE (300 Hz) is the highest backed vowel; however, this vowel in male SSE (541 Hz) is lowered by a distance of 241 Hz to a mid central vowel. The acoustic vowel space below (Figure 3.4) gives a full depiction of the two groups.

[16] Hillenbrand et al. (1995)
[17] Hillenbrand et al. (1995)

Figure 3.4

Comparative Vowel Space for Male SSE and Male GAE



The similarities between male SSE and male GAE account for only 27% (3 vowels). For both participants, the *trap* [æ] and *dress* [ɛ] vowels are fronted mid vowels. The *lot* [ɑ] sound is a low backed vowel for both groups. Eight out of 11 vowels (72%) are produced differently. These vowels are: *fleece* [i] and *kiss* [ɪ] sounds for SSE are fronted mid vowels while fronted high vowels for GAE. The [u] and [ʊ] in SSE are mid central sounds while backed sounds in GAE. The *goat* [o] and *thought* [ɔ] are low vowels for male SSE while they are mid vowels in GAE. The *strut* [ʌ] sound for SSE is a low central one while GAE's [ʌ] sound is a low backed one.

External Masking and Intelligibility

With such differences in vowel space between SSE and GAE, we can now focus on the external masking and intelligibility implications. Only external masking with acoustic distances of less than 20 Hz will be highlighted. Poor intelligibility is additionally considered to RFL. For male SSE, only the *trap* vowel [æ] presents a complete masking which impacts intelligibility. Table 3.5 below details these findings.

Table 3.5

External Masking and Intelligibility of Male SSE and Male GAE

Vowel Pairs	F1 Distance	External Masking Levels		RFL		Intelligibility Rating
[i] vs. [ɪ]	37 Hz	Moderate masking		95%		Average intelligibility
[ɪ] vs. [e]	43 Hz	Slight masking		80%		Fair intelligibility
[e] vs. [ɛ]	33 Hz	Moderate masking		53%		Fair intelligibility
[ɪ] vs. [ɛ]	**11 Hz**	**Complete masking**		**54%**		**Average intelligibility**
[ɛ] vs. [æ]	119 Hz	No masking		53%		Good intelligibility
[u] vs. [ʊ]	101 Hz	No masking		7%		Good intelligibility
[ʊ] vs. [o]	58 Hz	Slight masking		12%		Good intelligibility
[o] vs. [ɔ]	48 Hz	Slight masking		88%		Fair intelligibility
[ɔ] vs. [ɑ]	76 Hz	No masking		26%		Good intelligibility
[æ] vs. [ʌ]	108 Hz	No masking		68%		Good intelligibility
[ʌ] vs. [ɑ]	**18 Hz**	**Complete masking**		**65%**		**Average intelligibility**
[æ] vs. [ɑ]	**18 Hz**	**Complete masking**		**76%**		**Poor intelligibility**

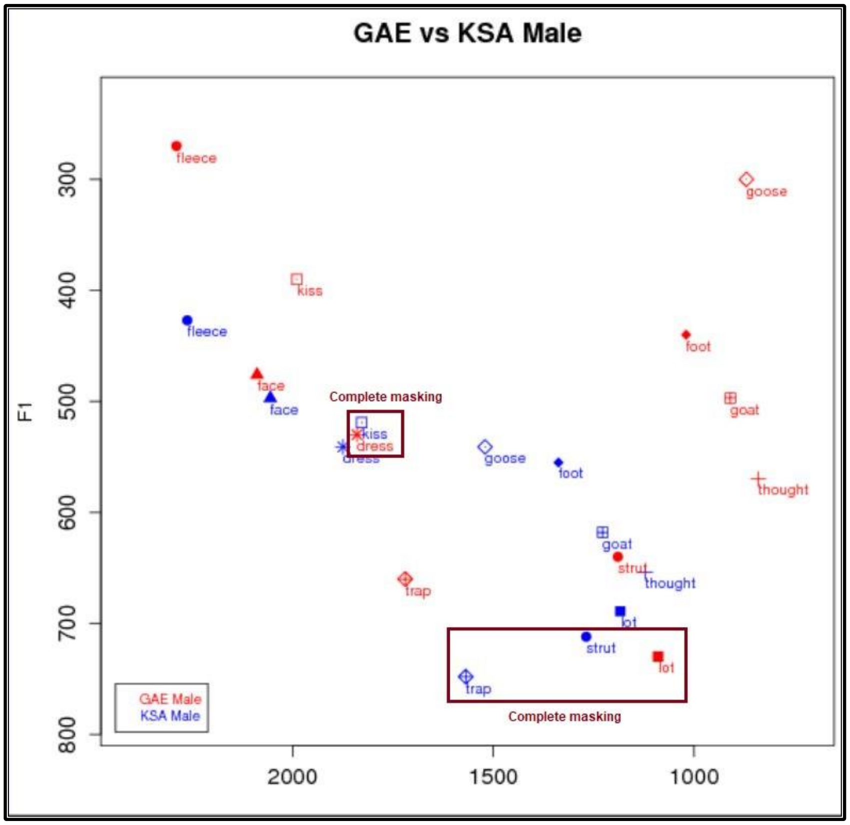
The male SSE *trap* vowel [æ] (748 Hz) shows a complete masking for GAEs *lot* vowel [ɑ] (730 Hz). With only an acoustic distance of 18 Hz and an RFL at 76%, poor intelligibility results for these sounds. For example, if a male Saudi speaker says <cap>, it will be misperceived as <cop> by a GAE hearer.

Two other vowels show complete masking. The *strut* vowel [ʌ] (712 Hz) completely masks the *lot* vowel [ɑ] in GAE (730 Hz) by 18 Hz. With an RFL of 65%, when some SSE speakers saying <cut>, it may be heard as <cot> by GAE hearers. The *kiss* vowel [ɪ] (519 Hz) produced by Saudi males shows a complete masking with the *dress* vowel [ɛ] (530 Hz) in GAE. With a distance of 11 Hz of separation, this only causes an average intelligibility issue. Words said by male Saudis like <pit> may be heard as <pet> by their American counterparts. Figure 3.5 illustrates the complete masking findings.

The *fleece* vowel [i] and the *face* vowel [e] present a moderate masking. The [i] sound in may cause an intelligibility problem for other Saudi speakers. With an RFL of 95%, if the *fleece* vowel [i] is not acoustically distinguished over 20 Hz for the GAE *kiss* vowel [ɪ], this will lead to poor intelligibility. The *face* vowel [e] is not as much at risk. The RFL of 53% indicates that intelligibility could still remain fair if a complete masking occurs with the GAE *dress* vowel [ɛ].

Figure 3.5

External Maskings for Male SSE and GAE vowels



Overall, the intelligibility of male SSE for external masking considerations is strong. Ten of eleven vowels (90%) show no ratings of poor intelligibility. Only the *trap* vowel [æ] leads to poor intelligibility and can be confused with the *lot* vowel [ɑ] in American speech. The *strut* vowel [ʌ] is also problematic for Saudi speakers. It can be confused with the *lot* vowel [ɑ] when American hearers are involved. With a low RFL of 65%, intelligibility is average for this pair. The GAE *dress* vowel [ɛ] is also completely masked by the SSE *kiss* vowel [ɪ]. This only causes average intelligibility issues considering an RFL at 54%.

Conclusion

The vowel space of male SSE includes only mid vowels and low vowels. They do not produce any high vowels. They realize 6 mid vowels (fronted [i], [e], [ɪ], [ɛ], and central [u], [ʊ]) and 5 low vowels (central [æ], [ʌ], [o], and backed [ɑ], [ɔ]). Their vowels are acoustically distinct from each other at 100%. The *goose* vowel [u] shows a complete masking with the *foot* vowel [ʊ] but a low RFL of 7% does not impact intelligibility.

When the male SSE vowel space is contrasted to the GAE vowel space, similarities account for only 27% of the vowels. Most male Saudi speakers produce their vowels in the central space of the mouth while GAE speakers do not produce any vowels in that area. Notable differences are present for the *fleece* [i], *kiss* [ɪ], *goose* [u], *foot* [ʊ], *goat* [o], *thought* [ɔ] and *strut* [ʌ] vowels. These differences lead to intelligibility issues. Specifically, the *trap* vowel [æ] shows a complete masking for the *lot* vowel [ɑ] in GAE. With an RFL at 76%, this leads to poor intelligibility. The second complete masking occurs when Saudi speakers produce the *strut* vowel [ʌ]. It can be confused with the *lot* vowel [ɑ] by a GAE hearer. The impact to intelligibility is average because of an RFL at 65%. Lastly the *kiss* vowel [ɪ] can be confused with the *dress* vowel [ɛ] in GAE. The average intelligibility rating is due to a relatively low RFL factor.

Chapter IV: Pedagogical Implications and Applications

Chapter Introduction

This chapter focuses on the pedagogical implications and applications. The first two sections discuss the characteristics and intelligibility implications specific to each gender group. The final section proposes some pedagogical steps our participants and educators can consider when teaching English to Saudi learners.

Implications for Female SSE

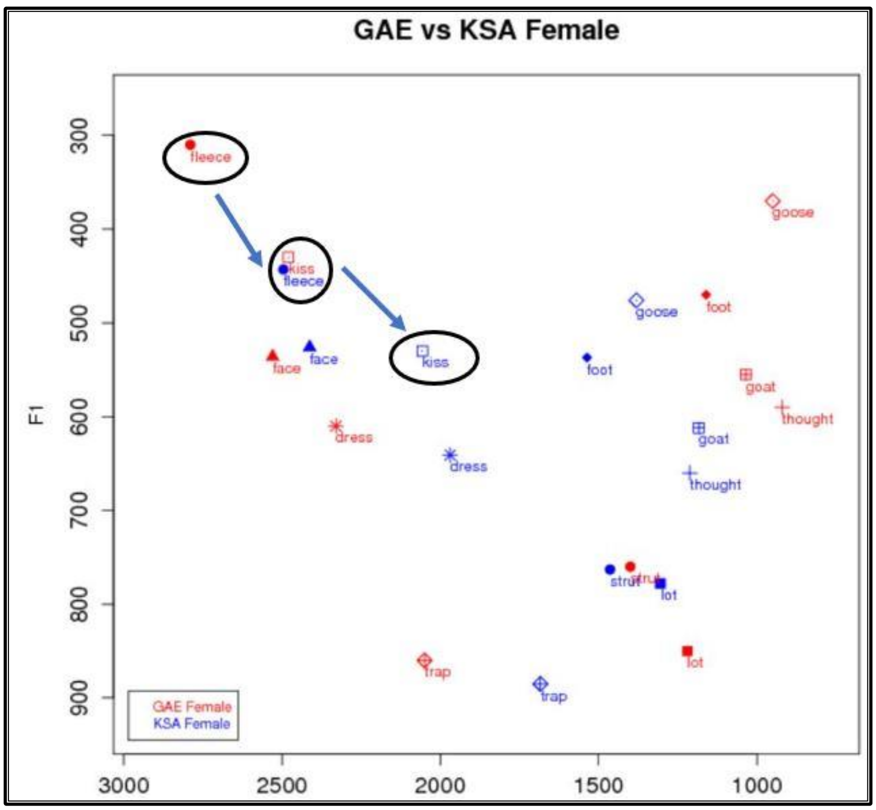
The characteristics of female SSE vowels have been detailed in Chapter Two. Overall, their vowel production is intelligible (81%) and only two vowels are problematic. Out of eleven vowels, only two pairs present a complete masking with only one pair causing poor intelligibility. The pair with poor intelligibility is the *kiss* vowel [ɪ] (530 Hz) because it masks the *face* vowel [e] (526 Hz). Similarly, when comparing the vowel space of female SSE to that of female GAE (Figure 2.5) for external masking and intelligibility, the *fleece* [i] and *kiss* [ɪ] vowels are the only problematic ones causing poor intelligibility ratings. They cause poor intelligibility because their RFL is high at 95% and 80% respectively. Based on the above findings, focus should be given to the SSE *fleece* vowel [i], *kiss* vowel [ɪ] and *face* vowel [e] when considering pedagogical steps.

Raising of High vowels. Research suggests that lax vowels are a major hurdle for most native Arabic speakers. As Al-Eisa explains "Arabic speakers are also not likely to have trouble producing tense vowels. The vowels that are challenging to them are lax vowels" (2003, p. 43). For our 23 female participants, they do not show any challenges in producing both tense and lax sounds. Specifically, they produce the *fleece* vowel [i] and *face* vowel [e] which are tense vowels. The *kiss* vowel [ɪ], which is a lax vowel, is also produced without difficulty. Rather, their poor intelligibility for those vowels stem from a reduced vowel space.

In the case of the SSE *fleece* vowel [i] (443 Hz), the vowel is lowered and causes a masking of the GAE lax *kiss* vowel [ɪ] (430 Hz). This shows that Saudi participants produce the lax vowel [ɪ]. For the SSE *kiss* vowel [ɪ] (530 Hz), a lowering occurs where masking of the GAE *face* vowel [e] happens. Figure 4.1 demonstrates such lowering of the [i] and [ɪ] vowels for Saudi participants (in blue) when compared to GAE (in red).

Figure 4.1

Female SSE Vowel Lowering



The comparison above makes it easy to see how female SSE vowels are generally more grouped together when compared to GAE. Almost all GAE vowels (in red) surround the SSE vowel space. The acoustic lowering of the SSE *fleece* vowel [i] and *kiss* vowel [ɪ] is similarly very apparent. Bringing phonetic awareness of this lowering could greatly help female Saudi speakers in distinguishing these vowels. Specifically, visualizing such lowering with PRAAT would facilitate understanding. To remediate such lowering, it is recommended that they raise their *fleece* vowel [i] and *kiss* vowel [ɪ] to levels close to GAE ones. Some pedagogical steps are proposed to improve intelligibility of these vowels in the next two sections.

Pedagogical Proposal for Differentiating [i] and [ɪ]. Raising the SSE *fleece* vowel [i] by at least 60 Hz is recommended to give enough acoustic distance to distinguish it from the current frequency (443 Hz). Using minimal pairs of tense [i] vowel and lax [ɪ] vowels are an efficient way to correct vowel masking and increase the acoustic distance needed (≥ 60 Hz). Table 4.1 gives a series of such pairs for the *fleece* [i] and *kiss* [ɪ] vowels.

Table 4.1

Minimal Pairs for Fleece [i] and Kiss [ɪ] Vowels

Vowel	Minimal Pairs								
[i]	beat	lead	greed	keep	reason	bead	cheek	peel	seep
[ɪ]	bit	lid	grid	kip	risen	bid	chick	pill	sip

Speakers should focus on the level of mouth aperture and tongue movement. To raise their *fleece* vowel [i], speakers should be guided in producing it with a smaller mouth aperture (smiling) while moving their tongue forward. These steps will have a direct impact on reducing their F1 and F2 frequencies closer to GAE ones. The SSE vowel [i] has a mean F1 of 443 Hz for these participants. They should practice with these minimal pairs until their measured *fleece* vowel [i] reaches at least 383 Hz. The next section will cover how to raise the *kiss* vowel [ɪ].

Pedagogical Proposal for Differentiating [ɪ] and [e]. The SSE *kiss* vowel [ɪ] (530 Hz) is lowered and masks the GAE tense *face* vowel [e] (536 Hz). It can be argued that the Saudi participants lowered their [ɪ] sound to a tense [e] sound because [ɪ] is missing from their L1. However, from the previous observation with the *fleece* vowel [i], we know that they can produce the lax vowel [ɪ] for *kiss*. Now that our participants are working to raise their *fleece* vowel [i] by at least 60 Hz, they will have space to raise their lax [ɪ] sound to the proper frequency. Using minimal pairs of combined tense vowel [i] versus lax vowel [ɪ] versus tense vowel [e] for the *fleece*, *kiss* and *face* sound will further bring into practice such raising of the vowels. Table 4.2 proposes such combination.

Table 4.2

Minimal Pairs for Fleece [i], Kiss [ɪ] and Face [e] Vowels

Vowel	Minimal Pairs							
[i]	beat	dean	lead	least	Pete	bead	cheek	meed	deal
[ɪ]	bit	din	lid	list	pit	bid	chick	mid	dill
[e]	bait	den	led	lest	pet	bed	check	Med	Dell

The target acoustic distance is to raise their current SSE *kiss* [ɪ] sound from 530 Hz to 470 Hz. While doing so, focus must be given to tongue movement. As Table 4.2 indicates, participants keep their tongue centered for the *kiss* vowel [ɪ]. They are encouraged to move their tongues forward significantly to close an acoustic gap for F2 of 423 Hz. Students will know that they have achieved their raising by distinguishing all three vowels by at least 60 Hz and their tongue movement by 200 Hz. Monitoring such activities in Praat is essential for success.

To summarize, focus should be given to the SSE *fleece* [i] and *kiss* [ɪ] vowels as they impeded intelligibility the most since their RFLs are respectively 95% and 80%. By raising their vowels, Saudi female speakers of English can achieve full vowel intelligibility. For that, the following is recommended: raise their SSE *fleece* [i] vowel from 443 Hz to at least 383 Hz and raise their SSE *kiss* [ɪ] vowel from 530 Hz to at least 470 Hz. Pedagogical applications of these recommendations will be covered in the third section of this chapter.

Implications for Male SSE

The F1 and F2 measurement of male were covered in Chapter Three. They can produce all 11 vowels and intelligibility is poor for only one vowel. The SSE *trap* vowel [æ] (748 Hz) and the GAE vowel *lot* [ɑ] (730 Hz) show a masking. With only 18 Hz of acoustic distance and an RFL of 76%, this leads to poor intelligibility. Focus is given to this last vowel pair to move our participants into full intelligibility.

Raising of the *Trap* [æ] Vowel. The male SSE *trap* [æ] sound is the lowest and most centered from their vowel inventory. To produce this sound, male Saudis have their jaws completely down (F1) while their tongue is in a neutral position (F2). To remediate the masking with the male GAE [ɑ] sound, a raising of the vowel of at least 60 Hz in F1 must be realized. Simultaneously, a raising of F2 by at least 200 Hz is also recommended. Speakers should open their mouths, lower their jaw, and push their tongue slightly forward. The next section proposes some steps to help raise the *trap* vowel [æ].

Pedagogical Proposal for Differentiating [æ] and [ɑ]. Participants produced their *trap* vowel [æ] on average for F1 around 758 Hz. The same vowel is produced in GAE at 660 Hz. This difference of more than 60 Hz signals that jaw position is noticeable between the two groups. Table 4.3 offers some minimal pairs to help raise phonetic awareness between [æ] and [ɑ].

Table 4.3

Minimal Pairs for Trap [æ] and Lot [ɑ] Vowels

Vowel	Minimal Pairs								
[æ]	cat	rad	rack	cap	scat	slap	adapt	faster	spat
[ɑ]	caught	rod	rock	cop	Scott	slop	adopt	foster	spot

Pedagogical Applications

If the Noticing Hypothesis is applied to pronunciation teaching, it can yield important benefits to students. Proponents of this hypothesis contend that “learner[s] must attend to and notice linguistic features” but also “make conscious comparisons between their own output and target language input” (Schmidt, 2010, p. 724). This hypothesis has been used in practical applications of acoustic phonetics in the past (Packer & Lorincz, 2013 and Ma, 2018). The use of acoustic phonetic measurements is beneficial in promoting pronunciation awareness because it can be used for two learning environments. Firstly, as a group setting such as a classroom and secondly for individual targeted learning.

In a classroom environment, this study on SSE vowel intelligibility can help teachers bring to notice the most problematic vowels first. For female SSE, teachers should focus on [i], [ɪ] and [e] vowels while for male SSE the [æ] vowel. Minimal pair activities provided above (Table 4.1, 4.2 & 4.3) do not require extensive class time to practice. Furthermore, the vowel space depictions of SSE provided in this study (Figure 2.4 and Figure 3.4) serve as a visual tool for vowel awareness. Many Saudi students who speak English can notice a difference in their speech when compared to native speakers. Spectrograms and vowel spaces give a visual reference to this difference. As Koffi (2019a, p. 18) advocates:

> Both teachers and students can benefit from acoustic phonetics because it gives them opportunity to visualize certain aspects of pronunciation in ways the IPA symbol or other method symbols cannot.

Acoustic phonetic analysis of this type can benefit individual learners by bringing to attention their individual pronunciation. Nowadays, communicative language teaching (CLT) does not allow for much focus on phonology in the classrooms. If curriculum allows, technology is used for pronunciation, but it is still very focused on attaining "mimicry" (Koffi, 2019a, p. 18) of native like sounds. Technology should be customized to increase student benefits as Munro and Derwing (2015, p. 393) explain:

> The common one-size-fits-all approach in which practice is offered in "everything" is unhelpful to teachers and students who need to focus their attention on issues that will genuinely improve their communication skills. An important challenge, then, is to find ways to apply the individualized attention that technology offers so that time is not wasted and interactional benefits are maximized.

Speech analysis softwares, such as Praat, offer simple tools in identifying individual student vowels. The accessibility to such technology for L2 teachers is simply revolutionary. As Koffi (2019a, p. 23) highlights "not so long ago, measuring English L2 speech acoustically would have been beyond the financial reach of many institutions." With little training, many L2 teachers could provide visual aid specific to each student in their classroom to improve their intelligibility. The pedagogical steps taken in the previous sections for female and male Saudi speakers are a clear example. An L2 teacher can pinpoint intelligibility issues and guide students to improving their speech on a 1-to-1 basis. This individual awareness can make students take charge of their speech intelligibility.

Conclusion

This study of vowel intelligibility in running speech offers great details into the L2 accented English of Saudi speakers. It provides a detailed analysis of the vowel production that cause intelligibility issues in Saudi spoken English. As Koffi (2012, p 231) brings forth in his analysis of Somali accented English, "targeted instruction based on findings such as the ones in this study can hasten and improve intelligibility." This work provides great insights for EFL/ESL educators as many "training programs incorporate little to no pedagogical training around pronunciation" (Sicola & Darcy, 2015, p. 472). These pedagogical steps also highlight the great tradition of combining acoustic phonetics and technology for the benefit of teachers and learners (Hincks, 2015, p. 516). Lastly, it feeds important data needed to make Saudi learners of English, independent pronunciation learners and advocates of their L2 English in the English as a Lingua Franca world.

Chapter V: Additional Insights into Saudi Spoken English

Chapter Introduction

The data collected for this thesis is extensive. 7,392 tokens in all were measured. However, since vowel intelligibility focuses mostly on F1 and F2, all the data available was not used in the previous chapters. In this chapter, acoustic correlates that are important for dealing with other aspects of Saudi-accented English are discussed briefly. The correlates that are highlighted here are F0, F3, F4, intensity and duration.

Pitch Features (F0)

The fundamental frequency (F0), gives broad information about speakers, mainly about their biological gender and age group (Ladefoged & Johnson, 2015. p. 264). Specifically, pitch changes "are associated with the rate of vibration of the vocal folds (Ladefoged & Johnson, 2015, p. 25). The JND threshold used by Koffi (Appendix A) for pitch is ≥ 1 Hz.

F0 for Female SSE. Table 5.1 shows pitch measurements for female SSE compared to female GAE. Saudi speakers have a higher pitch than their GAE counterparts. Pitch variation amongst female Saudi speakers is greater for the *thought* vowel [ɔ], *trap* vowel [æ] and *lot* vowel [ɑ].

Table 5.1

F0 Measurements for Female SSE and Female GAE

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**foot**	**goose**	**strut**
F0 Correlate	**[i]**	**[ɪ]**	**[e]**[18]	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**[19]	**[ʊ]**	**[u]**	**[ʌ]**
KSAF1	266	233	255	184	230	162	201	218	239	258	234
KSAF2	252	280	245	276	219	182	222	211	242	262	227
KSAF3	235	218	259	229	191	199	200	231	229	242	231
KSAF4	250	253	257	241	233	211	234	235	238	248	239
KSAF5	301	274	288	247	332	209	258	276	265	275	256
KSAF6	205	240	189	206	171	119	176	213	322	216	182
KSAF7	247	242	267	242	247	200	212	237	233	234	254
KSAF8	173	174	188	182	134	152	161	183	163	194	146
KSAF9	249	209	205	211	185	205	178	215	234	282	212
KSAF10	200	221	227	237	195	153	197	227	234	272	188
KSAF11	210	196	216	177	168	168	177	196	199	198	188
KSAF12	239	245	248	224	229	199	226	230	247	255	211
KSAF13	226	219	227	220	208	191	166	215	202	232	223
KSAF14	222	252	225	214	218	191	162	206	190	222	213
KSAF15	245	214	245	264	176	312	204	205	241	228	232
KSAF16	242	218	215	214	180	191	217	244	240	235	224
KSAF17	270	309	276	248	156	252	345	230	242	278	168
KSAF18	232	221	227	208	206	194	204	215	216	235	217
KSAF19	220	200	211	238	181	169	178	204	200	213	196
KSAF20	226	148	199	148	218	179	149	151	204	213	200
KSAF21	221	241	226	219	141	159	121	204	197	221	202
KSAF22	210	184	211	206	224	189	187	248	216	245	213
KSAF23	261	211	251	229	246	231	215	232	243	246	247
Mean	**235**	**226**	**233**	**220**	**204**	**192**	**200**	**219**	**228**	**239**	**213**
St. Deviation	27.1	35.4	27.2	29.2	42.2	38.3	44.0	24.6	31.3	24.8	27.2
P&B[20] (1952)	**235**	**232**	**219**	**223**	**210**	**212**	**216**	**217**	**232**	**231**	**221**

The measurements show that F0 for female SSE vowels is generally lower in pitch than GAE (63%). Saudi-accented *goose* vowel [u] (239 Hz) has the highest pitch of all the inventory. It is higher by 8 Hz from its GAE (231 Hz) counterpart. The [u] sound similarly has one of the lowest standard deviation at 24.8 Hz. The *lot* vowel [ɑ] (192 Hz) is the lowest in frequency for

[18] data taken from Hillenbrand et al. (1995)
[19] data taken from Hillenbrand et al. (1995)
[20] stands for Peterson & Barney

SSE. GAE female speakers produce the same [ɑ] sound 20 Hz higher (212 Hz). The average pitch sound for female SSE vowels is 219 Hz. The GAE average is only 3 Hz higher at 222 Hz.

F0 for Male SSE. Table 5.2 displays F0 measurements for male SSE compared to male GAE. Male Saudi speakers generally have a higher pitch than GAE speakers. The SSE *trap* vowel [æ] shows the highest variation in pitch amongst these participants. The range for that vowel varies from 125 Hz to 460 Hz.

Table 5.2

F0 Measurements for Male SSE and Male GAE

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**foot**	**goose**	**strut**
F0 Correlate	**[i]**	**[ɪ]**	**[e]**[21]	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**[22]	**[ʊ]**	**[u]**	**[ʌ]**
KSAM1	138	114	124	148	303	107	111	119	118	134	116
KSAM2	134	139	138	134	460	356	101	144	124	123	142
KSAM3	145	135	153	153	313	182	124	144	140	146	169
KSAM4	123	119	130	131	285	109	110	124	225	130	147
KSAM5	174	145	174	167	157	136	130	178	169	182	166
KSAM6	221	173	210	202	192	171	160	235	213	229	158
KSAM7	146	142	140	186	251	259	256	136	143	122	136
KSAM8	151	142	161	174	232	161	138	168	133	139	156
KSAM9	126	124	138	128	125	251	262	133	129	149	139
Mean	**151**	**137**	**152**	**158**	**258**	**192**	**155**	**153**	**155**	**150**	**148**
St. Deviation	30.3	17.5	26.8	25.9	99.7	81.9	61.7	36.1	39.2	34.6	16.6
P&B (1952)	**136**	**135**	**129**	**130**	**127**	**124**	**129**	**129**	**137**	**141**	**130**

Data for F0 male SSE shows that their vowels are higher in pitch for all vowels when compared to GAE (100%). The low central *trap* vowel [æ] is the highest in pitch for SSE (258 Hz). It is remarkably higher with 131 Hz of acoustic distance from the GAE *trap* vowel [æ] (127 Hz). The Saudi sound [æ] is also the highest for standard deviation at 99.7 Hz. Six participants (54%)

[21] from Hillenbrand et al. (1995)
[22] from Hillenbrand et al. (1995)

produce the *trap* vowel [æ] above 200 Hz. This is unusual for male speakers; however, the data was verified and confirmed. The *kiss* vowel [ɪ] (137 Hz) is the lowest in pitch for Saudi males. They produce that sound [ɪ] 2 Hz higher than their GAE counterparts (135 Hz). The average pitch sound for male SSE is 164 Hz. The GAE average is 33 Hz lower at 131 Hz.

Lip Rounding Features (F3)

The third formant (F3) provides data for degrees of lip rounding or retraction. Koffi (2016, p. 127) explains that F3 values are lower when the lips are rounded and higher when the lips are unrounded. Furthermore, Backstrom (2018, p. 29) provides the following boundaries for F3 for female and male speakers. Female lip rounding occurs when F3 is lower than 3000 Hz. Lip retraction for happens when F3 values are above 3000 Hz. Male lip rounding happens when F3 is below 2500 Hz. Above 2500 Hz, the lips are considered retracted. The acoustic threshold for F3 to distinguish between sounds is a JND ≥ 400 Hz (Appendix A).

F3 for Female SSE. Table 5.3 shows F3 measurements for female SSE compared to female GAE. There are no noticeable differences in lip rounding for these participants compared to GAE. Female SSE have the *thought* vowel [ɔ] as their most rounded vowel. This is different for GAE. Their most lip rounding occurs for the *goose* vowel [u].

Table 5.3

F3 Measurements for Female SSE and Female GAE

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**foot**	**goose**	**strut**
F3 Correlate	**[i]**	**[ɪ]**	**[e]**[23]	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**[24]	**[ʊ]**	**[u]**	**[ʌ]**
KSAF1	3131	2795	2906	2665	2657	2445	2494	2772	2600	2754	2572
KSAF2	3137	2925	3038	2861	3105	2978	2721	3028	2766	2848	2983
KSAF3	3273	3036	3147	3001	2733	2884	2656	3175	2996	2986	2716
KSAF4	2984	2769	3057	2853	2361	2589	2694	3077	2833	3091	2660
KSAF5	3098	2850	2896	2517	2621	3017	3213	3217	3110	3006	2929
KSAF6	2988	2800	2874	2769	2807	2521	2372	2834	2669	2680	2607
KSAF7	3090	2885	3014	3042	2390	3014	2636	3238	3023	2845	2606
KSAF8	2745	2676	2584	2488	2472	2584	2371	2626	2567	2649	2456
KSAF9	3072	2980	3007	2998	2968	2759	3045	3204	2934	3108	2757
KSAF10	3179	2767	2961	2792	2680	2560	2563	2819	2661	2638	2678
KSAF11	3063	2983	2998	3090	2606	2972	2333	2983	2752	2899	2827
KSAF12	3241	3182	3197	3016	2884	2928	3266	3304	3111	3315	2945
KSAF13	3013	2606	2905	2947	2634	2482	2459	2884	2756	2812	2541
KSAF14	3077	2944	3004	2759	2652	2667	2508	2807	2837	2808	2572
KSAF15	3124	2857	3000	2921	2573	2691	2553	2937	2873	2809	2507
KSAF16	2961	2893	3016	2915	2545	2776	2461	3172	3157	2908	2609
KSAF17	2992	2924	3008	3024	2579	2947	2577	3226	2994	2937	2767
KSAF18	3199	2953	3021	2770	2891	2702	2627	2927	2790	2913	2757
KSAF19	3177	3021	2947	3086	3005	2690	2715	2967	2902	3033	2929
KSAF20	3114	2882	2995	2855	2973	2679	2561	2762	2725	2752	2703
KSAF21	3153	3186	3069	3006	2904	2799	2476	2975	2898	2875	2698
KSAF22	3283	3048	2857	3072	2853	2909	2895	3052	2790	2879	2862
KSAF23	3073	3050	3069	2786	2515	2723	2723	3047	3046	3199	2629
Mean	**3094**	**2914**	**2981**	**2880**	**2713**	**2753**	**2649**	**3001**	**2860**	**2902**	**2709**
St. Deviation	117.6	143.2	118.7	169.2	204.8	176.8	248.9	182.3	166.6	169.7	148.4
P&B (1952)	**3310**	**3070**	**3047**	**2990**	**2850**	**2810**	**2710**	**2828**	**2680**	**2670**	**2780**

The most lip retracted sound for female SSE is the *fleece* vowel [i] (3094 Hz). This is similar to their GAE counterparts for *fleece* (3310 Hz). The acoustic distance between SSE and GAE is less than 400 Hz, which shows they have similar degree of lip spread for the [i] sound. The SSE *fleece* vowel [i] is also the most stable for F3 with the lowest standard deviation (117.6 Hz) of all vowels. The most lip rounded vowel for female SSE is the *thought* vowel [ɔ] (2649

[23] data taken from Hillenbrand et al. (1995)
[24] data taken from Hillenbrand et al. (1995)

Hz). This is a feature of female SSE for F3 compared to female GAE. Although this sound varies the most amongst Saudi speakers, it is well within the JND threshold (400 Hz) to qualify as a feature of their F3. The most lip rounded sound for GAE is the *goose* vowel [u] (2670 Hz). Overall, female SSE vowels have the same degree of lip rounding and spreading as GAE when considering the JND threshold of 400 Hz.

F3 for Male SSE. The male participants also show singularities in F3. Their most lip retracted vowel is the *goose* vowel [u]. Their most prominent lip rounding occurs for the *lot* vowel [ɑ]. Table 5.4 shows F3 measurements for male SSE compared to male GAE.

Table 5.4

F3 Measurements for Male SSE and Male GAE

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**foot**	**goose**	**strut**
F3 Correlate	**[i]**	**[ɪ]**	**[e][25]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o][26]**	**[ʊ]**	**[u]**	**[ʌ]**
KSAM1	2624	2578	2608	2597	2356	2436	2423	2664	2697	2812	2385
KSAM2	2645	2565	2648	2612	2607	2523	2544	2691	2426	2516	2562
KSAM3	2841	2741	2710	2723	2770	2673	2523	2737	2782	2829	2689
KSAM4	2747	2840	2708	2732	2527	2374	2529	2771	2536	2856	2310
KSAM5	3165	3037	2944	2939	2777	2594	2412	3064	2860	2981	2758
KSAM6	2714	2441	2579	2504	2505	2418	2561	2820	2717	2718	2363
KSAM7	2645	2641	2431	2444	2644	2413	2349	2610	2544	2799	2610
KSAM8	3023	2707	2830	2711	2627	2765	2735	2906	2732	3037	2571
KSAM9	2764	2740	2713	2714	2537	2488	2607	2698	2903	3364	2546
Mean	**2796**	**2699**	**2686**	**2664**	**2594**	**2520**	**2520**	**2773**	**2689**	**2879**	**2533**
St. Deviation	185.4	173.3	147.1	145.6	132.5	132.4	115.4	139.9	158.1	235.1	151.6
P&B (1952)	**3010**	**2550**	**2691**	**2480**	**2410**	**2440**	**2410**	**2459**	**2240**	**2240**	**2390**

For male SSE, the *goose* vowel [u] (2879 Hz) is the most lip spread from all of their inventory. This is a singularity of male Saudi speakers as their counterparts in GAE produce the

[25] from Hillenbrand et al. (1995)
[26] from Hillenbrand et al. (1995)

[u] sound as the most lip rounded one (2240 Hz) of all vowels. The nine participants produced this sound with great variance (235.1 Hz), yet still well underneath the 400 Hz JND threshold. The most lip rounded sound for male SSE are the *lot* [ɑ] and *thought* [ɔ] vowels (2520 Hz). This is also a second particularity for male Saudi speakers. GAE speakers have the most lip rounded sounds for the *foot* [ʊ] and *goose* [u] vowels (2240 Hz). Overall, for F3 measurements, male SSE have two noticeable differences with GAE speakers. SSE *foot* vowel [ʊ] and *goose* vowel [u] are both above the 400 Hz threshold when compared to GAE production.

Speaker Intrinsic Characteristics (F4)

The fourth formant gives information about individual speaker variations rather than linguistical cues. Ladefoged & Johnson define F4 as an “indicator of the individual’s head size” (2015, p. 222). Cao & Dellwo (2019, p. 620), in their study of vowels, note that the fourth formant is a measure of a speaker’s individuality and give details to which physiological characteristics:

> One possible interpretation is that F4 and F5 are sensitive to the laryngeal cavity (LC) shape (when LC is shortened, F5 and F4 increase). More recently, Takemoto et al. (2006) found that F4 was mainly determined by the LC geometry. Another study conducted by the same research group also found that the shape of the hypopharynx (i.e. laryngeal tube and piriform fossa), regardless of vowel type, showed relatively small within-speaker variation and relatively large between-speaker variation.

It is then expected that no major differences should be observed between the vowels in SSE for F4. As suggested by Ladefoged and Johnson (2015, p. 222), an average of F4 vowels will be calculated for Saudi speakers and compared to the average of GAE. We will use the JND threshold of ≥ 600 Hz (Koffi & Krause, 2020, p. 74) to determine if there are differences between their F4 and those of GAE speakers.

F4 for Female SSE. Table 5.5 shows F4 measurements for female SSE compared to female GAE. Overall, female Saudi speakers have a longer laryngeal cavity geometry than their American counterparts.

Table 5.5

F4 Measurements for Female SSE and Female GAE

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**foot**	**goose**	**strut**
F4 Correlate	**[i]**	**[ɪ]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[ʊ]**	**[u]**	**[ʌ]**
KSAF1	3972	3967	3878	3571	3477	3616	3817	3575	4050	3922	3645
KSAF2	4205	4426	4130	4232	3993	3959	4079	4112	4177	4207	3982
KSAF3	4408	4034	4069	4061	3872	3812	3584	4259	4276	4271	3909
KSAF4	3957	4106	4045	4029	3383	4008	4046	4205	4422	4212	3725
KSAF5	4424	3889	3955	3805	3919	3758	3856	4085	4081	4130	3799
KSAF6	4124	4289	4178	4197	4102	3790	3987	3850	4063	4098	3983
KSAF7	3738	3774	3901	3917	3342	3627	3600	3960	4180	4138	3662
KSAF8	3883	4194	3525	3786	3562	3704	3410	3872	3716	3559	3462
KSAF9	3800	4133	3585	3708	3659	3745	4106	3827	4175	4208	3694
KSAF10	4087	4064	4079	3940	3802	3559	3972	3842	4132	4187	3907
KSAF11	3823	4235	4159	4229	3697	3619	3872	3987	4160	4188	4024
KSAF12	4315	4470	4509	3785	4035	4110	4372	4303	4375	4292	4115
KSAF13	3967	3642	3821	3707	3789	3589	3615	4005	4008	3981	3583
KSAF14	4147	4008	4115	3830	3722	3582	3721	3853	4276	4107	3722
KSAF15	4086	4053	3957	3803	3527	3457	3712	3720	4015	3879	3434
KSAF16	3812	3879	4237	3674	3691	3869	3885	4077	4193	3954	3860
KSAF17	3647	3673	3832	3860	3369	3703	3454	3889	4218	3846	3581
KSAF18	4291	4088	3950	3577	3861	3804	3708	3954	4064	4153	3893
KSAF19	4165	4256	3893	3817	4104	3783	3706	3810	3932	3803	3798
KSAF20	4623	4454	4433	4055	4243	3835	3744	3751	4172	3981	3941
KSAF21	4342	4424	4232	4140	3748	3718	3721	3832	4146	4016	3948
KSAF22	4218	4266	4110	4052	3963	3849	4118	4205	4104	4041	3807
KSAF23	3951	4290	4119	3927	3449	3885	4056	3823	4530	4265	3857
Mean	**4086**	**4114**	**4031**	**3900**	**3753**	**3756**	**3832**	**3948**	**4151**	**4063**	**3797**
St. Deviation	247.9	238.1	229.8	196.8	256.7	155.2	235.1	185.1	167.4	178.8	179.1
Hillenbrand et al. (1995)	**4352**	**4334**	**4319**	**4294**	**4290**	**4299**	**3923**	**3927**	**4052**	**4115**	**4092**

The female SSE average measurement for F4 is 3948 Hz. The GAE average for F4 is 4181 Hz which is only 233 Hz more than SSE. There are no noticeable acoustic differences for F4 between female SSE and female GAE. The averages are below the JND of 600 Hz.

F4 for Male SSE. No major differences exist in F4 between Saudi males and American males. Table 5.6 shows F4 measurements for male SSE compared to male GAE.

Table 5.6

F4 Measurements for Male SSE and Male GAE

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**foot**	**goose**	**strut**
F4 Correlate	**[i]**	**[ɪ]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[ʊ]**	**[u]**	**[ʌ]**
KSAM1	3859	3793	3746	3945	4112	4127	3809	4132	3962	3627	3695
KSAM2	3954	3753	3700	3747	3635	3569	3611	3706	3690	4020	3468
KSAM3	3542	3501	3428	3541	3548	3428	3103	3466	3550	3697	3536
KSAM4	3897	2714	3988	3675	3458	3647	3643	3906	3669	3964	3487
KSAM5	3873	3844	3862	3821	3667	3503	3478	3750	3756	3805	3503
KSAM6	3682	3634	3636	3835	3939	3761	3708	3823	3822	3719	3766
KSAM7	4341	4221	4161	4079	3963	4003	4024	4193	4204	4405	3850
KSAM8	3780	3758	3723	3679	3638	3588	3463	3654	3640	3831	3644
KSAM9	3835	3933	3660	3772	3510	3290	3500	3523	3907	4478	3415
Mean	**3863**	**3683**	**3767**	**3788**	**3719**	**3657**	**3593**	**3795**	**3800**	**3950**	**3596**
St. Deviation	218.4	414.6	213.2	158.2	229.1	268.1	256.7	249.3	200.2	305.7	149.5
Hillenbrand et al. (1995)	**3657**	**3618**	**3649**	**3677**	**3624**	**3687**	**3486**	**3384**	**3400**	**3357**	**3557**

Male SSE average measurement for F4 is 3746 Hz. Their GAE counterparts' average is 3554 Hz. The acoustic distance between SSE fourth formant and GAE is below the JND threshold at 192 Hz. Based on this data, Saudi males have a shorter pharyngeal cavity geometry than Americans.

Intensity in Running Speech for SSE

Intensity is commonly referred to as loudness. Measured in decibels (dB), it helps to qualify how quiet or loud a speech sequence is perceived by hearers. Koffi (2019a, p. 42) reminds that intensity is not used in any language as a "distinctive feature;" however, for this intelligibility study, it will facilitate characterizing SSE. For two sounds to be perceived as different, they must have a JND $\geq$ 3 dB (2019a, p. 40). Finally, we will use the GAE data collected by Koffi & Krause (2020) for intensity of female (p.76) and male participants (p.85). Their study measured the intensity of the same vowels in running speech.

Intensity for Female SSE. Table 5.7 shows intensity measurements for female SSE compared to female GAE. In running speech, female SSE would be perceived as louder than GAE.

Table 5.7

Intensity Measurements for Female SSE and Female GAE

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**foot**	**goose**	**strut**
Intensity Correlate	**[i]**	**[ɪ]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[ʊ]**	**[u]**	**[ʌ]**
KSAF1	68	70	73	75	73	72	70	74	70	69	73
KSAF2	68	69	70	72	74	74	70	69	69	67	74
KSAF3	68	71	73	76	76	76	75	75	76	71	77
KSAF4	70	72	74	79	78	79	76	78	76	72	79
KSAF5	71	71	71	75	75	76	73	72	70	68	78
KSAF6	65	68	69	71	69	72	72	69	66	66	69
KSAF7	68	72	74	78	79	80	78	79	76	72	80
KSAF8	63	61	63	64	62	65	63	65	64	64	65
KSAF9	70	72	75	77	75	76	74	77	74	71	77
KSAF10	66	69	69	75	73	72	67	75	69	68	71
KSAF11	66	67	72	65	72	71	71	71	69	67	69
KSAF12	65	69	68	70	68	66	67	70	67	68	66
KSAF13	65	69	70	75	75	73	69	69	69	66	73
KSAF14	72	71	75	75	76	78	74	76	73	73	77
KSAF15	66	68	70	70	68	73	70	69	69	67	72
KSAF16	67	68	68	69	67	71	73	72	68	66	71
KSAF17	70	74	74	73	74	76	74	77	74	70	76
KSAF18	65	67	66	70	68	70	68	69	68	65	71
KSAF19	68	71	74	76	77	78	75	75	74	70	78
KSAF20	66	66	68	69	72	71	68	68	68	68	73
KSAF21	68	69	72	76	73	74	72	74	69	70	74
KSAF22	67	70	74	76	75	76	72	73	72	74	77
KSAF23	67	68	70	72	72	73	68	72	71	68	74
Mean	**67**	**69**	**71**	**73**	**73**	**74**	**71**	**73**	**70**	**69**	**74**
St. Deviation	2.2	2.6	3.1	3.9	4.1	3.8	3.5	3.7	3.3	2.6	4.0
Koffi & Krause (2020)	**55**	**55**	**54**	**58**	**57**	**57**	**54**	**55**	**57**	**55**	**56**

The average intensity for female SSE is 71 dB whilst the average for female GAE is 56 dB. With a difference of 15 dB, the intensity of female SSE in running speech is louder than their counterparts. This is an indication that female Saudis spoke in a more “lecturing voice”. The lower values in GAE indicate a more conversational voice. Most of the intensity (72%) of the running speech for Saudi speakers is unstable. Their standard deviations go beyond the ≥ 3 dB for eight vowels out of eleven. Female SSE in running speech would be perceived louder than female GAE.

Intensity for Male SSE. Male Saudi speech can be perceived as louder than GAE in running speech. Table 5.8 shows intensity measurements for male SSE compared to male GAE.

Table 5.8

Intensity Measurements for Male SSE and Male GAE

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**foot**	**goose**	**strut**
Intensity Correlate	**[i]**	**[ɪ]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[ʊ]**	**[u]**	**[ʌ]**
KSAM1	73	68	76	77	77	76	75	73	74	72	77
KSAM2	70	75	73	75	75	77	71	78	73	69	78
KSAM3	74	73	76	76	76	78	77	78	76	72	79
KSAM4	66	68	71	74	69	75	72	72	69	68	71
KSAM5	71	74	75	79	79	80	79	80	77	76	81
KSAM6	76	76	81	81	80	81	80	81	81	78	82
KSAM7	76	77	79	79	79	80	80	79	78	78	80
KSAM8	71	75	76	77	77	77	79	76	69	70	81
KSAM9	72	72	74	76	74	78	75	76	76	70	77
Mean	**72**	**73**	**76**	**77**	**76**	**78**	**76**	**77**	**75**	**73**	**78**
St. Deviation	3.1	3.3	3.0	2.2	3.3	2.0	3.4	3.0	4.0	3.8	3.3
Koffi & Krause (2020)	**61**	**61**	**62**	**60**	**60**	**59**	**55**	**57**	**62**	**59**	**63**

The average intensity of male SSE in running speech is 76 dB. Their GAE counterparts have an average of 60 dB in running speech. The SSE speech is louder by 16 dB and can be qualified as louder than GAE. Most SSE intensity measures are unstable (81%). Nine out of eleven vowels go beyond the ≥ 3 dB threshold for their standard deviation. Male SSE in running speech could be perceived as louder than GAE.

Duration in Running Speech for SSE

The last correlate for our insights in SSE is duration. Peña Coreas explains that duration "does not play a significant role in distinguishing vowels" (2019, p. 39). We will use the average duration for SSE vowels to contrast them with GAE. Any differences in average duration can be "identified as accentedness by other speakers of English" (Peña Coreas, 2019, p. 39). The acoustic threshold for perceiving duration differences is a JND of $\geq$ 10 ms. Finally, we will use the data provided by Koffi & Krause (2020) for GAE values in running speech.

Duration for Female SSE. Table 5.9 shows duration measurements for female SSE compared to female GAE. Vowels in running speech are similar in duration for both groups.

Table 5.9

Duration Measurements for Female SSE and Female GAE

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**foot**	**goose**	**strut**
Duration Correlate	**[i]**	**[ɪ]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[ʊ]**	**[u]**	**[ʌ]**
KSAF1	159	54	113	89	125	130	88	163	72	157	95
KSAF2	163	86	140	98	153	188	167	205	73	184	106
KSAF3	201	67	129	101	195	147	145	175	87	192	142
KSAF4	198	68	166	110	220	173	178	256	75	240	112
KSAF5	158	54	109	85	120	105	113	201	51	155	67
KSAF6	166	55	127	70	127	112	118	154	66	143	71
KSAF7	124	59	124	88	109	121	113	170	79	180	70
KSAF8	207	58	120	66	155	166	143	213	77	200	95
KSAF9	163	49	126	73	135	149	121	147	65	154	94
KSAF10	168	49	129	108	166	148	120	206	75	210	86
KSAF11	217	66	137	131	181	179	156	251	100	289	92
KSAF12	194	96	158	100	136	165	124	205	78	211	92
KSAF13	211	58	115	77	144	147	102	266	56	158	96
KSAF14	213	96	165	122	163	194	164	281	113	271	159
KSAF15	140	56	106	86	135	88	122	167	62	153	71
KSAF16	169	68	115	100	126	115	114	174	75	173	103
KSAF17	139	57	118	65	141	129	146	244	69	194	79
KSAF18	185	70	148	88	165	171	117	193	72	173	93
KSAF19	176	63	130	95	160	168	124	209	106	148	95
KSAF20	215	61	136	79	199	153	149	161	80	189	77
KSAF21	133	39	88	85	115	116	111	127	53	144	82
KSAF22	150	43	122	95	177	132	100	308	86	219	126
KSAF23	219	80	185	104	196	186	134	186	83	226	96
Mean	**177**	**63**	**131**	**92**	**154**	**147**	**129**	**203**	**76**	**190**	**96**
St. Deviation	29.5	14.9	22.1	16.8	30.0	29.3	23.1	46.3	15.4	39.8	22.5
Koffi & Krause (2020)	**156**	**97**	**127**	**82**	**160**	**187**	**116**	**124**	**108**	**177**	**138**

The average duration of female SSE vowels in running speech is 132 ms. Female GAE average duration is only 2 ms longer at 134 ms. There is no noticeable acoustic difference when it comes to duration between the two groups in running speech. The highest standard deviation for female Saudi vowel duration is the *goat* [o] sound at 46 .3 ms. The lowest deviation is the *kiss* [ɪ] sound at 14.9 ms. Female SSE vowels will be perceived as having a similar duration compared to female GAE in running speech.

Duration for Male SSE. The duration of male SSE vowels in running speech is longer when compared to GAE. Table 5.10 shows duration measurements for male SSE compared to male GAE.

Table 5.10

Duration Measurements for Male SSE and Male GAE

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**foot**	**goose**	**strut**
Duration Correlate	**[i]**	**[ɪ]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[ʊ]**	**[u]**	**[ʌ]**
KSAM1	140	129	166	134	113	124	111	291	93	269	107
KSAM2	197	61	94	112	168	136	90	188	91	173	80
KSAM3	155	68	120	86	131	129	111	141	94	166	98
KSAM4	137	69	127	99	134	122	122	191	83	182	105
KSAM5	140	81	209	190	182	168	118	345	116	234	114
KSAM6	213	71	139	134	185	145	137	309	102	254	91
KSAM7	161	72	177	143	180	146	170	318	134	289	121
KSAM8	181	90	152	142	168	152	195	306	122	228	108
KSAM9	126	281	134	125	164	118	111	213	80	282	81
Mean	**161**	**102**	**146**	**129**	**158**	**138**	**129**	**256**	**102**	**231**	**101**
St. Deviation	29.8	69.9	34.1	30.0	25.9	16.4	33.1	72.6	18.5	47.4	14.2
Koffi & Krause (2020)	**165**	**99**	**112**	**100**	**161**	**200**	**112**	**74**	**81**	**172**	**105**

Duration average for male SSE is 150 ms in running speech. Their GAE counterparts have a lower duration average of 126 ms. With a difference of 24 ms, duration is noticeable when it comes to vowels of male SSE. This may be an indication of their focus on articulation. The highest standard deviation for duration of vowels in SSE is the [o] sound (72.6 ms). The [ʌ] sound has the lowest deviation at 14.2 ms. Male SSE vowels would be perceived as longer in duration for running speech when compared to GAE. This could signal accentedness to other speakers of English.

Summary

The insights found in this chapter offer a complete picture of the acoustic phonetic characteristics of the vowel produced by the participants. Even though these features do not contribute much to intelligibility, they provide us with additional data that can be used for a comprehensive analysis of Saudi-accented English vowels.

Female SSE is characterized by having a higher pitch than their GAE counterparts. Their most lip rounded vowel is the *thought* vowel [ɔ] which differs from the GAE *goose* vowel [u]. In running speech, SSE vowels are perceived to be louder. The Saudi female participants have the vowel duration when compared to GAE. For male SSE, pitch is higher than GAE. Lip rounding is different for Saudi males when compared to US males. Their lips are unrounded for the *goose* vowel [u] while their counterparts have the *fleece* vowel [i] as unrounded. The *lot* vowel [ɑ] is the most rounded of all Saudi-accented English. However, in GAE, the vowel that involves the most rounding of the lips is the *goose* vowel [u]. In running speech, male SSE vowels are perceived to be louder than GAE. Lastly, Saudi vowels are longer in duration when compared to American English vowels.

The overall goal has been to assess the intelligibility of Saudi-accented English. In the process of doing so, a large quantity of data has been collected that can be put to a wide variety of uses, including but not limited to Automatic Speech Recognition (ASR), Assistive Technology for Impairments (ATI), Forensic Phonetics and Computer Assisted Pronunciation Teaching (CAPT).

As Hincks (2015, p. 514) emphasizes “ASR for non-native speech needs to be adapted so that the underlying phonetic models encompass a wider variety of possible productions.” The present study contributes to this gap in technology for L2 learners and specifically offers a complete phonetic inventory for Saudi spoken English in running speech with 7,392 tokens. ASR is well developed for Saudi Arabic pioneered by phonetician Mansour Alghamdi. This study offers an additional set of data for Saudi spoken English.

Saudi students with varying impairments can also benefit from the present study. Assistive Technology for Impairments offers tools for orthopedic, hearing and speech impairments (Cennamo, Ross & Ertmer, 2010). Voice Recognition Technology (VRT) gives students with orthopedic impairments, access to controlling devices. If the device needed is only available to speakers of English, the present study could offer some speech characteristics of SSE as data to enable Saudi users. For hearing impairments, Telecommunications Devices for the Deaf (TDD) allows speech to be recognized and typed automatically for the impaired user. In a classroom setting, such technology allows impaired students to remain in classes and interact without needing special instruction. Having the technology used in EFL classes for SSE can further reduce the isolation of impaired students and invite them to participate with their peers. For speech impaired Saudi speakers, the use of the data in this study can help them with synthesized speech. As part of augmentative or alternative communication (AAC) devices, synthesized speech allows impaired students to use sounds to communicate. When these sounds are similar in characteristics to those in the classroom, the isolation barrier is reduced significantly. A student with a hearing disability could still attend an EFL class with his peers and sound just like them.

Additionally, part of Computer Assisted Pronunciation Teaching (CAPT) technology, pronunciation teaching relies heavily on input and feedback of L2 speech. The proposed SSE data can provide specific acceptable ranges of validation exclusive to Saudi-accented English.

Lastly, the growing field of forensic phonetics can benefit from this study. Forensic phonetics is typically used for speaker profiling in law enforcement settings. It focuses on voice comparison, speaker analysis and speaker identification. As Saudi spoken English becomes a staple English in ELF, complete phonetic resources found in this study can benefit the forensics field.

References

Abu-Rabia, S. (1999). The Effect of Arabic Vowels on the Reading Comprehension of Second- and Sixth-Grade Native Arab Children. Journal of psycholinguistic research. 28. 93-101. 10.1023/A:1023291620997.

Al-Eisa, A. (2003). An ESL/EFL teacher's guide to English-Arabic interlingual phonology. Thesis (M.A.) --St. Cloud State University, 2003.

Alghamdi, M.M. (1998). A spectrographic analysis of Arabic vowels: a cross-dialect study. J. King Saud University, 10(1), 3-24.

Alotaibi, Y.A., & Hussain, A. (2010). Comparative Analysis of Arabic Vowels using Formants and an Automatic Speech Recognition System.

Backstrom, M. (2018). "An Acoustic Phonetic Analysis of Northern Minnesota English Vowel Spaces." Culminating Projects in English. 144.

Boersma, P. & Weenink, D. (2019). Praat: doing phonetics by computer [Computer program]. Version 6.1.06, retrieved 8 November 2019 from http://www.praat.org/

Cao, H. & Dellwo, V. (2019). The role of the first five formants in three vowels of mandarin for forensic voice analysis.

Cennamo, K, S., Ross, J, D., & Ertmer, P, A. (2010). Technology Integration for Meaningful Classroom Use A Standards-Based Approach. Cengage Learning; 2nd Edition (January 1, 2013).

Fletcher, H. (1953). Speech and Hearing in Communication. New York: D. Van Nostrand Company, Inc.

Fogerty, D. & Humes, L. (2012). The role of vowel and consonant fundamental frequency, envelope, and temporal fine structure cues to the intelligibility of words and sentences. The Journal of the Acoustical Society of America 131:2, 1490-1501

Hillenbrand, J., Getty, L.A., Clark, M. J., & Wheeler, K. (1995). Acoustic Characteristics of American English Vowels. Journal of the American Acoustical Society, 97 (5) 3099-3111.

Hincks, R. (2015). Technology and Learning Pronunciation. The Handbook of English Pronunciation, 1st Ed. p.507-519. Edited by Marnie Reed and John M. Levis. John Wiley & Sons, Inc.

International Phonetic Association. (2010). Handbook of the International Phonetic Association: A guide to the use of the international phonetic alphabet. New York: Cambridge University Press.

Kendall, T. & Erik, R. T. (2010). Vowels: Vowel Manipulation, Normalization, and Plotting in R. R package, version 1.1. [Software Resource: http://ncslaap.lib.ncsu.edu/tools/norm/]

Kent, R., D., & Read, C. (2002). The acoustic analysis of speech. (2nd ed.). Canada: Singular Thomson learning

Khalil, S. (2014). "Comparative Study of the Acoustic Vowel Space of Egyptian English vowels and General American English Vowels," Linguistic Portfolios: Vol.3, Article 8.

Koffi, E. (2012). Intelligibility Assessment and the Acoustic Vowel Space: An Instrumental Phonetic Account of the Production of Lax Vowel Vowels by Somali Speakers. In J. Levis & K. Levelle (Eds.). Proceedings of the 3rd Pronunciation in Second Language

Learning and Teaching Conference, Sept.2011. (pp.216---232), Ames, IA: Iowa State University.

Koffi, E. (2016). "The Acoustic Correlates of [±ATR] Vowels: An Analysis by Reference Levels of Anyi Vowels," Linguistic Portfolios: Vol. 5, Article 9.

Koffi, E. & Lesniak, F. G. (2019). "A Longitudinal Acoustic Phonetic Study of English Vowels by a Panamanian Speaker, "Linguistic Portfolios: Vol. 8, Article 5. Available at: https://repository.stcloudstate.edu/stcloud_ling/vol8/iss1/5

Koffi, E. (2019a). Relevant acoustic phonetics of L2 English: Focus on Intelligibility. (Course Manuscript), St. Cloud, MN.

Koffi, E. (2019b). "An Acoustic Phonetic Analysis of the Intelligibility of Nepali-Accented English Vowels," Linguistic Portfolios: Vol. 8, Article 9. Available at: https://repository.stcloudstate.edu/stcloud_ling/vol8/iss1/9

Koffi, E.(2019c). An Acoustic Phonetic Account of the Confusion between [l] and [n] by some Chinese Speakers, Linguistic Portfolios: Vol. 8, Article 6. Available at: https://repository.stcloudstate.edu/stcloud_ling/vol8/iss1/6.

Koffi, E. (2020). "A Tutorial on Acoustic Phonetic Feature Extraction for Automatic Speech Recognition (ASR) and Text-to-Speech (TTS) Applications in African Languages," Linguistic Portfolios: Vol.9, Article 11, p.130-153

Koffi, E. & Krause, J. (2020). "Speech Style Variation of Vowels in Citation Form vs. Running Speech: Intelligibility Implications for AI-Enabled Devices," Linguistic Portfolios: Vol. 9, Article 6.

Kotby, M. N., Saleh, M., Hegazi, M., Gamal, N., Abdel Salam, M., Nabil, A., Fahmi, S. (2011). The Arabic Vowels: Features and Possible Clinical Application in Communication Disorders. Folia Phoniatr Logop 2011; 63:171-177. doi: 10.1159/000316323

Labov, W., Rosenfelder, I., & Fruehwald, J. (2013). One hundred years of sound changes in Philadelphia: Linear incrementation, reversal, and reanalysis. Language, 89(1). Linguistic Society of America.

Ladefoged, P., & Johnson, K. (2015). A course in phonetics (7th ed.). Cengage Learning: Stamford, CT, USA.

Liljencrantz, J., & Lindblom, B. (1972). Numerical simulation of vowel quality systems: The role of perceptual contrast. Linguistic Society of America. 48(4).

Ma, L. (2018). "An Acoustic Phonetic Analysis of Mandarin English Vowel Spaces." Culminating Projects in English. 145.

Munro, M., & Derwing, T. (2015). Intelligibility in Research and Practice: Teaching Priorities. The Handbook of English Pronunciation, 1st Ed. p.377-396. Edited by Marnie Reed and John M. Levis. John Wiley & Sons, Inc.

Packer, C. B., & Lorincz, K. (2013). Acoustic vowel space analysis of an English language learner. Linguistic Portfolios, 2, Article 3.

Peña Coreas, J. A. (2019). "Salvadorian-Accented English Vowels Produced by Teachers of English as a Foreign Language". Culminating Projects in TESL. 11. https://repository.stcloudstate.edu/tesl_etds/11

Peterson, G., E., & Barney, H., L. (1952). Control methods in a study of the vowels. The Journal of the Acoustic Society in America, 24(2).

Prator, C. H., & Robinett, B. W. (1972). Manual of American English Pronunciation.3rd ed. New York: Holt, Rinehart and Winston.

Saadah, E. (2011). The Production of Arabic Vowels by English L2 Learners and Heritage Speakers of Arabic. USA. University of Illinois, Urbana-Champaign

Schmidt, R. (2010). Attention, awareness, and individual differences in language learning. In W. M. Chan, S. Chi, K. N. Cin, J. Istanto, M. Nagami, J.W. Sew, T. Suthiwan, & I. Walker, Proceedings of CLaSIC 2010, Singapore, December 2-4 (pp. 721-737). Singapore: National University of Singapore, Centre for Language Studies.

Sicola, L., & Darcy, I. (2015). Integrating Pronunciation into the Language Classroom. The Handbook of English Pronunciation, 1st Ed. p.471-487. Edited by Marnie Reed and John M. Levis. John Wiley & Sons, Inc.

Zahrani, M. (2017). A Study on the Impact of Arabic Diglossia on L2 learners of Arabic: Examining Motivation and Perception. Arab World English Journal. Theses / Dissertation (ID 190) Pp.1-70. DOI: https://dx.doi.org/10.24093/awej/th.190

Appendix A: JND Thresholds for Acoustic Correlates

The following table provides "the main reference levels/absolute thresholds/Just Noticeable Differences (JNDs)" (Koffi, 2019a:56).

	Segments/Suprasegments	**Acoustic Correlates**	**JND Thresholds**
Vowels			
1.	Vowels	F1	> 60 Hz
2.	Vowels	F2	≥ 200 Hz
3.	Vowels	F3	≥ 400 Hz
4.	Vowels	F4	≥ 600 Hz[27]
Consonants			
1.	Stops	Voice Onset Time (VOT)	≥ 25, 34, 42 ms
2.	Fricatives and affricates	Intensity	≥ 3 dB
3.	Nasals	F2 for [m] and [n]	≥ 200 Hz
4.	Nasals	F3 for [n] and [ŋ]	≥ 400 Hz
5.	Approximants	F3	≥ 400 Hz
6.	Voicing ratios	Length in milliseconds	40/60
Suprasegmentals			
1.	Stress	F0/Pitch	≥ 1 Hz
2.	Intensity	Intensity	≥ 3dB
3.	Duration	Length in milliseconds	≥ 10 ms/ ≥ 17 ms
4.	Duration of σ	In conversation/reading	200 ms
5.	Duration of a word	In conversation/reading	200 to 600 ms
6.	Duration of a phrase	In conversation/reading	1,000 to 3,000 ms

[27] This JND was added from the original table. Fourth formant JND is found in Koffi & Krause (2020:74)

Appendix B: Summary of the Relative Functional Loads (RFL)

The following table provides a summary of the Relative Functional Load applied to the eleven vowel sounds in the English language. Table adapted from Koffi, (2019a, pp. 45- 46)

Words	Vowel Phonemes	Percentage
bit / bat	/ɪ/ vs. /æ/	100
beet / bit	/i/ vs. /ɪ/	95
bought / boat	/ɔ/ or /ɑ/ vs. /o/	88
bit / but	/ɪ/ vs. /ʌ/	86
bit / bait	/ɪ/ vs. /e/	80
cat / cot	/æ/ vs. /ɔ/ or /ɑ/	76
cat / cut	/æ/ vs. /ʌ/	68
cot / cut	/ɔ/ or /ɑ/ vs. /ʌ/	65
bit / bet	/ɪ/ vs. /ɛ/	54
bet / bait	/ɛ/ vs. /e/	53
bet / bat	/ɛ/ vs. /æ/	53
coat / coot	/o/ vs. /ʊ/	51
beet / boot	/i/ vs. /ʊ/	50
bet / but	/ɛ/ vs. /ʌ/	50
bought / boot	/ɔ/ or /ɑ/ vs. /ʊ/	50
pet / pot	/ɛ/ vs. /ɑ/	45
*cot / caught	/ɔ/ vs. /ɑ/	26
box / books	/ɑ/ or /ɔ/ vs. /ʊ/	18
pill / pull	/ɪ/ vs. /ʊ/	13.5
pull / pole	/ʊ/ vs. /o/	12
*put / putt	/ʊ/ vs. /ʌ/	9
*pull / pool	/ʊ/ vs. /u/	7
cam / calm	/æ/ vs. /ɑ/	4.5

*Stands for variable pronunciations among different dialects of English. /ɑ/ and /ɔ/ are listed together because they have merged or are merging many dialects of American English.

Appendix C: Elicitation Paragraph

Read the following text as naturally as possible. We recommend practicing it several times before recording it so that you get a smooth reading that resembles how you talk.

Please call Stella. Ask her to bring these things with her from the store: Six good spoons of fresh snow peas, five thick slabs of blue cheese, and maybe a foot-long sandwich as a snack for her brother Bob. We also need a small plastic snake, the little yellow book, a rubber duck, and a paper I-pad. She should not forget the dog video game and the big toy frog for the kids. She must leave the faked gun at home, but she may bring the ten sea turtles, the mat that my mom bought, and the black rug. She can scoop these things into three red bags and two old backpacks. We will go meet her, Sue, Jake, and Jenny Wednesday at the very last train station. The station is between the bus stop and the cookie store on Flag Street. We must meet there at 12 o'clock, for sure. The entrance is at the edge of the zoo in Zone 4 under the zebra sign. York's Treasure Bank is the tall building in the left corner. She cannot miss it.

Appendix D: Linguistic Profile Questionnaire

Participant Information

*All the information collected remains **anonymous** and **unidentifiable**. Thank you for being a participant and advancing the field of Phonetics.*

*Purpose: This study aims to record sounds of Saudi English. Reading proficiency is not being measured. **Only** the sounds that are produced by the speakers.*

1. What is your first name?
2. How old are you? OR What is your year of birth?
3. In what country were you born?
4. Which city?
5. What cities have you lived **in** Saudi Arabia?
6. From which region is your Saudi Arabic from? (Jeddah, Najd, etc.)
7. Where have you lived **outside** of Saudi Arabia?
8. If you have, from what age to what age have you lived outside KSA?
    a. Where specifically (city)?
    b. Did you use English there?
9. At what age do you remember first speaking English?
10. At what age did you start learning English at school?
11. What would you say contributed the most to your English fluency?

Appendix E: Linguistic Profile Data for Female Participants

Participant	Age	Country of Birth	City of Birth	Cities lived in KSA	Dialect ascription	Inner Circle life	If yes, age outside KSA	If yes, English used?	Age of 1st Spoken English	Age of 1st Eng class	Major Contrib. to fluency
KSAF1	35	KSA	Jeddah	Jeddah Riyadh	Hijazi	UK / Canada	Adult	Yes	12	13	Entertainment
KSAF2	30	KSA	Riyadh	Riyadh	Najdi	-	-	-	12	11	NS Interaction
KSAF3	27	KSA	Riyadh	Riyadh	Najdi	-	-	-	7	7	Entertainment/NS Interaction
KSAF4	31	KSA	Riyadh	Riyadh	Najdi	UK / USA	Child/Adult	Yes	12	12	Entertainment
KSAF5	35	KSA	Riyadh	Riyadh	Najdi	-	-	-	5	11	Entertainment
KSAF6	37	KSA	Riyadh	Riyadh	Najdi	USA	Child	Yes	7	3	Inner Cirlce Childhood
KSAF7	34	KSA	Riyadh	Riyadh	Southern	-	-	-	11	11	Sibling
KSAF8	31	KSA	Riyadh	Riyadh	Najdi	-	-	-	12	16	Entertainment/NS Interaction
KSAF9	45	KSA	Riyadh	Riyadh	Najdi	UK	Adult	Yes	18	17	NS Interaction
KSAF10	29	KSA	Medina	Medina Riyadh	Hijazi	-	-	-	6	6	Entertainment
KSAF11	29	KSA	Riyadh	Riyadh	Najdi	USA	Child	Yes	8	5	School
KSAF12	35	KSA	Riyadh	Riyadh	Najdi	USA	Child	No	6	6	Inner Cirlce Childhood
KSAF13	30	KSA	Taif	Taif Riyadh	Hijazi	USA	Child	Yes	6	6	Inner Cirlce Childhood
KSAF14	34	KSA	Jubail	Dammam Riyadh	Gulf	USA	Child	Yes	13	13	NS Interaction
KSAF15	35	KSA	Riyadh	Riyadh	Hijazi	-	-	-	12	12	Entertainment
KSAF16	30	KSA	Riyadh	Riyadh	Najdi	Australia	Adult	Yes	11	11	Entertainment
KSAF17	41	KSA	Riyadh	Riyadh	Najdi	Canada	Child	Yes	13	13	Entertainment/NS Interaction
KSAF18	34	KSA	Riyadh	Riyadh	Najdi	-	-	-	6	12	Entertainment/NS Interaction
KSAF19	37	KSA	Riyadh	Riyadh	Najdi	USA	Adult	Yes	13	13	NS Interaction
KSAF20	31	KSA	Riyadh	Jubail Jeddah Hail Riyadh	Northern	-	-	-	12	12	School
KSAF21	19	KSA	Ottowa, CA	Riyadh	Najdi	Canada	Child	Yes	5	5	Inner Cirlce Childhood
KSAF22	25	KSA	Jeddah	Jeddah Riyadh Taif Tabuk	Najdi	-	-	-	13	9	Entertainment/NS Interaction
KSAF23	30	KSA	Riyadh	Riyadh	Najdi	UK/US	Adult	Yes	7	7	Tutoring

Appendix F: Linguistic Profile Data for Male Participants

Participant	Age	Country of Birth	City of Birth	Cities lived in KSA	Dialect ascription	Inner Circle life	If yes, age outside KSA	if yes, English used?	Age of 1st Spoken English	Age of 1st Eng class	Major Contrib. to fluency
KSAM1	30	KSA	Riyadh	Riyadh	Najdi	-	-	-	21	15	NS Interaction
KSAM2	28	USA	Michigan	Riyadh	Najdi	USA	Child/Adult	Yes	5	5	Inner Circle Childhood
KSAM3	28	KSA	Makkah	Makkah Riyadh	Najdi	Canada	Adult	Yes	5	9	Entertainment
KSAM4	31	KSA	Buraydah	Buraydah Riyadh	Najdi	USA	Adult	Yes	16	15	Entertainment/NS Interaction
KSAM5	38	KSA	Riyadh	Riyadh	Najdi	-	-	-	19	13	School
KSAM6	39	KSA	Riyadh	Riyadh	Najdi	-	-	-	16	13	Entertainment
KSAM7	53	KSA	Medina	Riyadh	Najdi	-	-	-	19	13	NS Interaction
KSAM8	32	KSA	Riyadh	Riyadh	Northern	UK/US	Adult	Yes	11	11	NS Interaction
KSAM9	28	KSA	Riyadh	Hafir Batin	Najdi	USA	Adult	Yes	24	17	NS Interaction

Appendix G: Female SSE Data Summary

Female SSE Summary											
Vowel Sound	fleece	kiss	face	dress	trap	lot	thought	goat	foot	goose	strut
Vowel	**[i]**	**[ɪ]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[ʊ]**	**[u]**	**[ʌ]**
F0	235	226	233	220	204	192	200	219	228	239	213
F1	443	530	526	641	885	778	660	612	537	476	763
F2	2496	2057	2413	1969	1684	1305	1212	1184	1537	1381	1464
F3	3094	2914	2981	2880	2713	2753	2649	3001	2860	2902	2709
F4	4086	4114	4031	3900	3753	3756	3832	3948	4151	4063	3797
Intensity	67	69	71	73	73	74	71	73	70	69	74
Duration	177	63	131	92	154	147	129	203	76	190	96

Female GAE vs Female SSE Summary												
Vowel Sound		fleece	kiss	face	dress	trap	lot	thought	goat	foot	goose	strut
Vowel		**[i]**	**[ɪ]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[ʊ]**	**[u]**	**[ʌ]**
GAE F	F0	235	232	219	223	210	212	216	217	232	231	221
KSA F	F0	235	226	233	220	204	192	200	219	228	239	213
GAE F	F1	310	430	536	610	860	850	590	555	470	370	760
KSA F	F1	443	530	526	641	885	778	660	612	537	476	763
GAE F	F2	2790	2480	2530	2330	2050	1220	920	1035	1160	950	1400
KSA F	F2	2496	2057	2413	1969	1684	1305	1212	1184	1537	1381	1464
GAE F	F3	3310	3070	3047	2990	2850	2810	2710	2828	2680	2670	2780
KSA F	F3	3094	2914	2981	2880	2713	2753	2649	3001	2860	2902	2709
GAE F	F4	4352	4334	4319	4294	4290	4299	3923	3927	4052	4115	4092
KSA F	F4	4086	4114	4031	3900	3753	3756	3832	3948	4151	4063	3797
Intensity GAE F	Ints	55	55	54	58	57	57	54	55	57	55	56
Intensity KSA F	Ints	67	69	71	73	73	74	71	73	70	69	74
Duration GAE F	Dur	156	97	127	82	160	187	116	124	108	177	138
Duration KSA F	Dur	177	63	131	92	154	147	129	203	76	190	96

Appendix H: Male SSE Data Summary

Male SSE Summary											
Vowel Sound	fleece	kiss	face	dress	trap	lot	thought	goat	foot	goose	strut
Vowel	**[i]**	**[ɪ]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[ʊ]**	**[u]**	**[ʌ]**
F0	151	137	152	158	258	192	155	153	155	150	148
F1	427	519	497	541	748	689	654	618	555	541	712
F2	2263	1828	2056	1875	1569	1184	1122	1228	1338	1521	1269
F3	2796	2699	2686	2664	2594	2520	2520	2773	2689	2879	2533
F4	3863	3683	3767	3788	3719	3657	3593	3795	3800	3950	3596
Intensity	72	73	76	77	76	78	76	77	75	73	78
Duration	161	102	146	129	158	138	129	256	102	231	101

GAE Male vs KSA Male Summary												
Vowel Sound		fleece	kiss	face	dress	trap	lot	thought	goat	foot	goose	strut
Vowel		**[i]**	**[ɪ]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[ʊ]**	**[u]**	**[ʌ]**
GAE M	F0	136	135	129	130	127	124	129	129	137	141	130
KSA M	F0	151	137	152	158	258	192	155	153	155	150	148
GAE M	F1	270	390	476	530	660	730	570	497	440	300	640
KSA M	F1	427	519	497	541	748	689	654	618	555	541	712
GAE M	F2	2290	1990	2089	1840	1720	1090	840	910	1020	870	1190
KSA M	F2	2263	1828	2056	1875	1569	1184	1122	1228	1338	1521	1269
GAE M	F3	3010	2550	2691	2480	2410	2440	2410	2459	2240	2240	2390
KSA M	F3	2796	2699	2686	2664	2594	2520	2520	2773	2689	2879	2533
GAE M	F4	3657	3618	3649	3677	3624	3687	3486	3384	3400	3357	3557
KSA M	F4	3863	3683	3767	3788	3719	3657	3593	3795	3800	3950	3596
Intensity KSA M	Ints	61	61	62	60	60	59	55	57	62	59	63
Intensity KSA M	Ints	72	73	76	77	76	78	76	77	75	73	78
Duration GAE M	Dur	165	99	112	100	161	200	112	74	81	172	105
Duration KSA M	Dur	161	102	146	129	158	138	129	256	102	231	101

Appendix I: All Female SSE Measurements for 7 Correlates

Vowel sound and name										
fleece	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**foot**	**goose**	**strut**
[i]	[ɪ]	[e]*	[ɛ]	[æ]	[ɑ]	[ɔ]	[o]*	[ʊ]	[u]	[ʌ]
V1: please V2: peas V3: meet	V1: with V2: thick V3: is	V1: maybe V2: faked V3: paper	V1: yellow V2: edge V3: red	V1: ask V2: pad V3: mat	V1: Bob V2: dog V3: frog	V1: for V2: bought V3: corner	V1: old V2: go V3: zone	V1: good V2: book V3: cookie	V1: blue V2: scoop V3: zoo	V1: rubber V2: duck V3: must

	KSAF1								KSAF2							
	F0	**F1**	**F2**	**F3**	**F4**	**Ints**	**Dur**	**IPA**	**F0**	**F1**	**F2**	**F3**	**F4**	**Ints**	**Dur**	**IPA**
V1	307	433	2416	3024	3602	73	154	[i]	343	356	2357	2987	4214	76	123	[i]
V2	205	400	2754	3108	4104	61	202		207	371	2626	3303	4232	63	232	
V3	287	438	2613	3262	4211	71	123		207	441	2616	3122	4169	65	136	
	266	423	2594	3131	3972	68	159	σ	252	389	2533	3137	4205	68	163	σ
V1	216	440	1730	2532	4158	71	38	[ɪ]	218	447	1846	2798	4461	69	48	[ɪ]
V2	247	491	2444	2877	3717	72	64		234	466	2299	2912	4436	72	85	
V3	237	510	2343	2976	4028	68	62		389	528	1966	3066	4381	68	126	
	233	480	2172	2795	3967	70	54	σ	280	480	2037	2925	4426	69	86	σ
V1	247	493	2705	3145	3831	70	138	[e]	249	568	2476	3068	4159	73	126	[e]
V2	255	490	2586	2981	3757	73	134		240	509	2437	3093	4155	69	170	
V3	265	529	2062	2592	4047	76	68		247	473	2451	2954	4078	68	125	
	255	504	2451	2906	3878	73	113	σ	245	516	2454	3038	4130	70	140	σ
V1	166	691	1601	2692	3566	75	54	[ɛ]	257	561	1657	3001	4181	76	53	[ɛ]
V2	232	479	2351	2819	3338	78	137		347	654	2063	2824	4290	69	121	
V3	154	485	2033	2486	3809	72	76		224	697	1864	2759	4226	73	121	
	184	551	1995	2665	3571	75	89	σ	276	637	1861	2861	4232	72	98	σ
V1	247	964	1661	2764	3194	77	108	[æ]	247	1191	1697	3118	3993	76	139	[æ]
V2	182	824	1689	2628	3822	67	127		129	923	1618	3040	3927	67	161	
V3	263	812	1180	2581	3415	75	142		282	1023	1714	3159	4059	79	161	
	230	866	1510	2657	3477	73	125	σ	219	1045	1676	3105	3993	74	153	σ
V1	166	773	1125	2662	3492	70	158	[ɑ]	116	835	1122	2998	3910	73	170	[ɑ]
V2	226	678	1441	2566	3810	76	136		216	905	1353	3128	3991	77	173	
V3	95	768	1268	2108	3548	70	97		216	815	1346	2808	3978	73	221	
	162	739	1278	2445	3616	72	130	σ	182	851	1273	2978	3959	74	188	σ
V1	213	595	1105	2215	3946	71	70	[ɔ]	222	553	930	2525	3930	67	126	[ɔ]
V2	180	474	871	2814	3693	73	132		224	830	1280	3150	3994	77	312	
V3	212	589	1016	2454	3814	68	64		221	581	1018	2488	4315	68	64	
	201	552	997	2494	3817	70	88	σ	222	654	1076	2721	4079	70	167	σ
V1	118	542	888	3015	3548	74	165	[o]	172	704	1010	3529	4106	69	215	[o]
V2	297	562	1249	2875	3833	77	175		242	582	1183	2778	4130	76	185	
V3	240	578	1183	2427	3344	71	151		220	509	1272	2777	4102	62	216	
	218	560	1106	2772	3575	74	163	σ	211	598	1155	3028	4112	69	205	σ
V1	246	496	1789	2550	3952	73	69	[ʊ]	257	523	1956	2819	4226	69	62	[ʊ]
V2	197	579	1088	2546	3847	68	100		231	504	1207	2692	4125	75	121	
V3	275	521	1193	2705	4353	70	47		240	453	1426	2789	4181	64	37	
	239	532	1356	2600	4050	70	72	σ	242	493	1529	2766	4177	69	73	σ
V1	232	474	1627	2839	3650	68	133	[u]	239	619	1482	2917	4202	66	190	[u]
V2	331	400	1044	2666	4059	76	124		318	383	1089	2799	4276	72	163	
V3	211	420	1346	2758	4058	63	215		230	450	1436	2829	4145	65	200	
	258	431	1339	2754	3922	69	157	σ	262	484	1335	2848	4207	67	184	σ
V1	241	709	1220	2354	3636	76	110	[ʌ]	247	772	1356	2588	3767	81	90	[ʌ]
V2	213	748	1472	2549	3825	73	110		220	915	1363	2974	4073	77	187	
V3	250	736	1398	2815	3476	70	65		215	922	1388	3388	4108	64	42	
	234	731	1363	2572	3645	73	95	σ	227	869	1369	2983	3982	74	106	σ

KSAF3

	F0	F1	F2	F3	F4	Ints	Dur	IPA
V1	257	495	2719	3165	4391	70	157	[i]
V2	209	451	2685	3263	4238	68	268	
V3	241	585	2846	3391	4596	67	178	
	235	510	2750	3273	4408	68	201	σ
V1	204	566	1722	3016	4320	70	55	[ɪ]
V2	240	512	2362	2753	3353	76	67	
V3	212	594	2110	3340	4430	68	81	
	218	557	2064	3036	4034	71	67	σ
V1	260	609	2630	3164	4040	71	138	[e]
V2	237	514	2545	3014	4089	72	141	
V3	280	466	2707	3264	4080	77	109	
	259	529	2627	3147	4069	73	129	σ
V1	230	677	1656	3169	4370	77	63	[ɛ]
V2	239	582	2260	3040	4341	75	132	
V3	220	635	1950	2796	3472	76	109	
	229	631	1955	3001	4061	76	101	σ
V1	216	926	1627	2787	3679	78	175	[æ]
V2	89	828	1783	2879	4283	73	111	
V3	270	883	1731	2535	3655	78	299	
	191	879	1713	2733	3872	76	195	σ
V1	163	861	1252	2873	3903	76	100	[ɑ]
V2	229	807	1456	3004	4068	77	203	
V3	205	775	1324	2777	3467	77	138	
	199	814	1344	2884	3812	76	147	σ
V1	202	691	1318	2413	3550	76	107	[ɔ]
V2	195	637	1108	3098	4093	75	255	
V3	204	844	1288	2457	3111	76	74	
	200	724	1238	2656	3584	75	145	σ
V1	216	720	1054	3568	4389	80	181	[o]
V2	245	624	1228	3026	4305	75	257	
V3	233	522	1453	2931	4085	71	88	
	231	622	1245	3175	4259	75	175	σ
V1	238	502	1839	2980	4252	77	76	[ʊ]
V2	218	643	1270	3017	4130	79	147	
V3	233	494	1298	2991	4448	72	40	
	229	546	1469	2996	4276	76	87	σ
V1	251	587	1676	3003	4150	71	144	[u]
V2	263	616	1227	2949	4496	73	145	
V3	213	456	1242	3007	4167	71	288	
	242	553	1381	2986	4271	71	192	σ
V1	229	775	1512	2662	3900	80	93	[ʌ]
V2	206	818	1505	2856	3992	78	168	
V3	258	815	1499	2630	3835	75	165	
	231	802	1505	2716	3909	77	142	σ

KSAF4

	F0	F1	F2	F3	F4	Ints	Dur	IPA
V1	296	498	2040	2708	3692	75	173	[i]
V2	220	438	2459	3125	4038	67	260	
V3	234	589	2279	3119	4143	69	161	
	250	508	2259	2984	3957	70	198	σ
V1	219	493	1668	2800	4272	73	50	[ɪ]
V2	231	587	2316	2891	4290	69	86	
V3	309	571	2065	2616	3756	75	68	
	253	550	2016	2769	4106	72	68	σ
V1	297	583	2634	3291	4312	77	155	[e]
V2	244	535	2466	2868	3887	74	174	
V3	232	567	2638	3012	3938	72	171	
	257	561	2579	3057	4045	74	166	σ
V1	237	777	1537	3005	4359	81	81	[ɛ]
V2	260	666	2093	2953	3781	79	151	
V3	228	674	2001	2603	3947	79	98	
	241	705	1877	2853	4029	79	110	σ
V1	258	975	1673	2471	3531	80	106	[æ]
V2	196	915	1707	2652	3295	77	210	
V3	247	879	1591	1961	3323	79	346	
	233	923	1657	2361	3383	78	220	σ
V1	201	837	1247	2876	4166	79	169	[ɑ]
V2	227	853	1403	2860	4106	81	207	
V3	206	794	1297	2033	3752	78	143	
	211	828	1315	2589	4008	79	173	σ
V1	236	654	1108	2368	3867	72	87	[ɔ]
V2	239	840	1340	3235	4322	81	366	
V3	229	668	977	2481	3950	75	81	
	234	720	1141	2694	4046	76	178	σ
V1	232	648	942	3620	4471	80	237	[o]
V2	246	603	970	2882	4299	77	367	
V3	229	598	1172	2731	3846	79	166	
	235	616	1028	3077	4205	78	256	σ
V1	236	490	1672	2766	4462	78	72	[ʊ]
V2	224	644	1289	2969	4402	77	108	
V3	256	540	1295	2765	4403	73	46	
	238	558	1418	2833	4422	76	75	σ
V1	231	457	1335	3210	3886	72	169	[u]
V2	289	411	879	3136	4372	72	233	
V3	226	471	1207	2927	4380	74	319	
	248	446	1140	3091	4212	72	240	σ
V1	223	747	1327	2449	3575	79	63	[ʌ]
V2	223	896	1545	2616	4165	79	169	
V3	272	812	1376	2915	3437	80	106	
	239	818	1416	2660	3725	79	112	σ

	KSAF5								KSAF6							
	F0	F1	F2	F3	F4	Ints	Dur	IPA	F0	F1	F2	F3	F4	Ints	Dur	IPA
V1	340	519	2355	3156	4979	78	148	[i]	236	441	2399	2963	4216	64	179	[i]
V2	274	446	2470	3150	4419	67	233		167	413	2364	2976	4294	64	228	
V3	291	507	1919	2988	3876	70	93		213	473	2149	3026	3864	67	93	
	301	490	2248	3098	4424	71	158	σ	205	442	2304	2988	4124	65	166	σ
V1	239	536	1870	2844	4279	72	45	[ɪ]	256	523	1774	2542	4106	71	41	[ɪ]
V2	288	584	2383	2893	3923	70	33		229	498	2172	2733	4309	68	69	
V3	297	582	2004	2814	3465	73	85		235	548	2036	3127	4454	65	57	
	274	567	2085	2850	3889	71	54	σ	240	523	1994	2800	4289	68	55	σ
V1	312	588	2417	3078	4101	70	107	[e]	238	441	2445	2995	4126	70	108	[e]
V2	251	537	2394	2753	3499	71	147		116	490	2334	2822	4146	69	165	
V3	303	578	2288	2858	4267	73	74		214	462	2379	2806	4263	70	110	
	288	567	2366	2896	3955	71	109	σ	189	464	2386	2874	4178	69	127	σ
V1	260	695	1859	2565	3501	76	66	[ɛ]	201	649	1708	2874	4341	72	46	[ɛ]
V2	249	686	2078	2913	4280	76	126		207	578	2078	2790	4080	71	111	
V3	234	581	1876	2073	3634	74	63		211	619	1834	2643	4170	70	53	
	247	654	1937	2517	3805	75	85	σ	206	615	1873	2769	4197	71	70	σ
V1	274	1035	1763	3052	4194	76	101	[æ]	218	826	1572	2758	4307	72	65	[æ]
V2	404	752	1822	2726	4207	70	137		75	781	1675	2664	4209	68	132	
V3	320	878	1752	2087	3357	79	122		222	817	1515	2999	3791	68	184	
	332	888	1779	2621	3919	75	120	σ	171	808	1587	2807	4102	69	127	σ
V1	165	747	1226	3050	3771	74	143	[ɑ]	123	747	1164	2613	3678	73	132	[ɑ]
V2	242	770	1480	3143	3894	79	120		119	709	1354	2582	3810	72	103	
V3	220	698	1174	2859	3611	75	54		116	721	1289	2370	3884	71	102	
	209	738	1293	3017	3758	76	105	σ	119	725	1269	2521	3790	72	112	σ
V1	247	679	1187	3259	3752	73	64	[ɔ]	211	630	1276	2119	3971	72	55	[ɔ]
V2	258	582	1152	3110	4091	73	202		125	765	1420	2813	4049	74	238	
V3	271	709	1224	3272	3726	74	75		192	578	1242	2186	3941	70	63	
	258	656	1187	3213	3856	73	113	σ	176	657	1312	2372	3987	72	118	σ
V1	230	688	1003	3451	3949	74	165	[o]	207	510	969	3094	3790	66	154	[o]
V2	346	619	1154	3258	4213	75	333		238	552	1166	2719	3851	75	251	
V3	254	554	1340	2942	4093	69	105		194	567	1491	2691	3910	68	58	
	276	620	1165	3217	4085	72	201	σ	213	543	1208	2834	3850	69	154	σ
V1	247	516	1864	2848	4175	70	55	[ʊ]	207	537	1856	2693	4152	72	75	[ʊ]
V2	247	616	1162	3451	4377	74	73		543	607	1110	2674	3793	66	89	
V3	302	568	1439	3032	3692	68	27		217	451	1382	2642	4245	62	36	
	265	566	1488	3110	4081	70	51	σ	322	531	1449	2669	4063	66	66	σ
V1	245	530	1489	3053	3976	67	131	[u]	222	488	1670	2853	4078	66	107	[u]
V2	318	565	1380	3072	4378	72	135		232	466	1297	2649	4185	67	90	
V3	262	558	1608	2895	4037	66	201		195	446	1336	2538	4031	66	233	
	275	551	1492	3006	4130	68	155	σ	216	466	1434	2680	4098	66	143	σ
V1	246	771	1244	2732	3490	82	85	[ʌ]	210	617	1329	2288	3962	71	49	[ʌ]
V2	264	801	1464	3277	3978	79	70		107	711	1491	2642	3982	71	105	
V3	259	766	1445	2779	3931	75	46		231	660	1511	2891	4006	67	61	
	256	779	1384	2929	3799	78	67	σ	182	662	1443	2607	3983	69	71	σ

	KSAF7								KSAF8							
	F0	F1	F2	F3	F4	Ints	Dur	IPA	F0	F1	F2	F3	F4	Ints	Dur	IPA
V1	296	421	2225	2618	3306	71	117	[i]	238	460	2250	2756	3936	65	186	[i]
V2	196	391	2800	3224	3714	66	148		110	376	2253	2729	3863	60	297	
V3	249	436	2706	3428	4194	69	108		173	386	2464	2750	3851	65	139	
	247	416	2577	3090	3738	68	124	σ	173	407	2322	2745	3883	63	207	σ
V1	214	513	2109	2902	4311	71	31	[ɪ]	120	453	1595	2588	4122	60	33	[ɪ]
V2	248	563	2414	2792	3480	75	83		200	434	2105	2643	4079	65	62	
V3	266	545	2550	2961	3533	70	65		203	590	1818	2797	4383	60	81	
	242	540	2357	2885	3774	72	59	σ	174	492	1839	2676	4194	61	58	σ
V1	281	490	2421	3088	3962	73	153	[e]	188	445	2003	2535	3470	62	115	[e]
V2	270	542	2560	3111	3993	77	157		197	420	2304	2585	3484	65	158	
V3	251	700	2249	2843	3748	74	63		179	380	2309	2633	3622	62	89	
	267	577	2410	3014	3901	74	124	σ	188	415	2205	2584	3525	63	120	σ
V1	245	722	1703	3001	3712	81	57	[ɛ]	172	606	1643	2537	4584	64	56	[ɛ]
V2	260	646	2485	3191	4094	79	134		192	547	1991	2528	3443	67	91	
V3	223	591	2239	2936	3947	76	74		183	519	1917	2401	3331	63	53	
	242	653	2142	3042	3917	78	88	σ	182	557	1850	2488	3786	64	66	σ
V1	265	903	1620	2669	3368	80	88	[æ]	109	772	1580	2264	3220	67	144	[æ]
V2	171	1019	1848	2383	3089	78	98		107	732	1626	2735	3920	53	146	
V3	306	883	1640	2118	3569	80	143		188	768	1591	2418	3546	67	176	
	247	935	1702	2390	3342	79	109	σ	134	757	1599	2472	3562	62	155	σ
V1	179	874	1182	2933	3519	79	138	[ɑ]	147	769	1262	2722	3840	66	145	[ɑ]
V2	240	814	1237	3366	3840	82	112		142	743	1550	2639	3837	64	180	
V3	183	866	1290	2745	3524	80	115		167	707	1441	2391	3435	65	175	
	200	851	1236	3014	3627	80	121	σ	152	739	1417	2584	3704	65	166	σ
V1	216	681	1217	2341	3604	75	54	[ɔ]	175	578	1080	2329	3398	65	59	[ɔ]
V2	204	924	1431	2935	3393	81	207		183	501	1097	2727	3639	63	284	
V3	218	734	1143	2634	3805	78	80		125	665	1248	2058	3195	63	87	
	212	779	1263	2636	3600	78	113	σ	161	581	1141	2371	3410	63	143	σ
V1	235	695	1014	3585	4046	81	139	[o]	182	566	1049	2931	4128	68	217	[o]
V2	240	582	1009	2959	4008	79	192		190	614	1075	2466	3599	65	233	
V3	237	705	1172	3171	3826	78	181		179	551	1254	2483	3890	63	191	
	237	660	1065	3238	3960	79	170	σ	183	577	1126	2626	3872	65	213	σ
V1	239	490	1647	2914	4302	76	43	[ʊ]	187	481	1778	2533	3690	68	57	[ʊ]
V2	197	676	1068	3253	3895	79	149		110	561	1525	2595	3913	61	143	
V3	263	580	1205	2904	4343	74	45		194	455	1420	2575	3545	64	33	
	233	582	1306	3023	4180	76	79	σ	163	499	1574	2567	3716	64	77	σ
V1	226	461	1377	2863	4109	67	148	[u]	177	417	1592	2609	3522	63	194	[u]
V2	237	478	858	2797	4187	76	155		215	434	1153	2705	3610	67	118	
V3	241	500	1238	2877	4120	73	237		191	451	1525	2635	3545	63	290	
	234	479	1157	2845	4138	72	180	σ	194	434	1423	2649	3559	64	200	σ
V1	253	843	1331	2610	3802	83	55	[ʌ]	90	671	1342	2223	3081	65	88	[ʌ]
V2	228	903	1544	2956	3439	80	99		174	716	1548	2500	3850	64	132	
V3	283	840	1384	2252	3746	79	58		175	644	1336	2647	3457	66	65	
	254	862	1419	2606	3662	80	70	σ	146	677	1408	2456	3462	65	95	σ

	KSAF9								KSAF10							
	F0	F1	F2	F3	F4	Ints	Dur	IPA	F0	F1	F2	F3	F4	Ints	Dur	IPA
V1	288	398	2404	2956	3759	73	162		242	433	2496	2947	4304	66	138	
V2	205	420	2509	3018	4038	66	217	[i]	121	390	2442	3274	3759	64	244	[i]
V3	256	455	2813	3242	3605	71	112		237	452	2576	3316	4200	70	123	
	249	424	2575	3072	3800	70	163	σ	200	425	2504	3179	4087	66	168	σ
V1	171	532	1371	2922	4290	70	40		191	527	1771	2557	4107	65	33	
V2	208	501	2326	2822	3957	77	55	[ɪ]	238	483	2270	2896	4149	74	66	[ɪ]
V3	248	567	1957	3198	4153	70	54		236	538	1918	2850	3938	69	50	
	209	533	1884	2980	4133	72	49	σ	221	516	1986	2767	4064	69	49	σ
V1	134	647	2365	3094	3591	73	117		210	538	2433	2973	3944	68	133	
V2	245	578	2381	2955	3540	78	153	[e]	235	477	2400	2949	4102	73	155	[e]
V3	237	496	2483	2972	3624	74	110		237	444	2498	2963	4192	67	101	
	205	573	2409	3007	3585	75	126	σ	227	486	2443	2961	4079	69	129	σ
V1	190	622	1710	3046	3731	72	56		241	644	1802	2989	3910	76	82	
V2	231	729	2212	3096	3898	78	105	[ɛ]	252	562	2196	2859	4134	75	148	[ɛ]
V3	213	718	1873	2853	3497	81	59		219	657	1822	2528	3778	74	94	
	211	689	1931	2998	3708	77	73	σ	237	621	1940	2792	3940	75	108	σ
V1	230	886	1285	3133	3559	80	152		224	855	1500	2780	3863	75	96	
V2	75	869	1678	2835	3907	68	93	[æ]	118	929	1878	2736	4050	66	172	[æ]
V3	250	1028	1672	2937	3513	77	160		243	860	1771	2524	3495	78	230	
	185	927	1545	2968	3659	75	135	σ	195	881	1716	2680	3802	73	166	σ
V1	238	786	1228	2925	3725	78	133		80	751	1128	2711	3567	68	172	
V2	178	725	1227	2617	3723	74	211	[ɑ]	208	720	1279	2723	3822	77	126	[ɑ]
V3	199	677	1163	2736	3787	78	104		173	781	1173	2246	3289	72	147	
	205	729	1206	2759	3745	76	149	σ	153	750	1193	2560	3559	72	148	σ
V1	96	631	1016	2904	4078	71	89		201	565	952	2473	3892	66	71	
V2	229	526	951	3282	4141	75	197	[ɔ]	192	535	992	2757	4261	72	208	[ɔ]
V3	211	606	856	2949	4101	77	78		199	538	944	2461	3765	65	83	
	178	587	941	3045	4106	74	121	σ	197	546	962	2563	3972	67	120	σ
V1	187	599	904	3459	3785	75	209		215	514	936	3080	3747	73	151	
V2	230	616	1318	2944	3923	79	154	[o]	255	556	1190	2653	3975	78	249	[o]
V3	229	637	1191	3210	3773	77	79		212	711	1141	2725	3804	75	219	
	215	617	1137	3204	3827	77	147	σ	227	593	1089	2819	3842	75	206	σ
V1	213	520	1835	2861	4116	75	64		242	482	1855	2689	4122	72	63	
V2	244	569	1211	2993	4114	76	91	[ʊ]	196	504	1193	2615	4107	68	124	[ʊ]
V3	245	511	1780	2950	4296	73	41		266	417	1316	2680	4169	68	38	
	234	533	1608	2934	4175	74	65	σ	234	467	1454	2661	4132	69	75	σ
V1	238	490	1338	3005	4119	71	134		223	449	1561	2614	4059	66	156	
V2	321	528	1116	3145	4327	73	80	[u]	296	445	1180	2677	4424	70	123	[u]
V3	288	553	1394	3174	4179	69	250		297	484	1129	2624	4079	69	351	
	282	523	1282	3108	4208	71	154	σ	272	459	1290	2638	4187	68	210	σ
V1	224	764	1431	2648	3684	79	72		221	766	1272	2190	3706	76	70	
V2	177	807	1497	2696	3711	77	124	[ʌ]	130	789	1326	2686	3833	71	141	[ʌ]
V3	235	880	1319	2927	3687	75	88		214	707	1562	3158	4184	68	48	
	212	817	1415	2757	3694	77	94	σ	188	754	1386	2678	3907	71	86	σ

	KSAF11								KSAF12							
	F0	F1	F2	F3	F4	Ints	Dur	IPA	F0	F1	F2	F3	F4	Ints	Dur	IPA
V1	245	447	2257	2889	3475	71	219	[i]	302	450	2355	3177	4324	70	193	[i]
V2	179	377	2645	3255	4417	61	248		209	420	2765	3235	4110	61	282	
V3	206	420	2386	3047	3577	67	186		208	508	2792	3311	4512	64	109	
	210	414	2429	3063	3823	66	217	σ	239	459	2637	3241	4315	65	194	σ
V1	172	525	1697	2883	4362	65	57	[ɪ]	229	532	1885	3225	4713	70	36	[ɪ]
V2	226	536	2501	2944	3816	73	77		253	521	2416	3220	4604	70	63	
V3	191	605	2054	3122	4528	63	66		253	518	2435	3103	4093	67	189	
	196	555	2084	2983	4235	67	66	σ	245	523	2245	3182	4470	69	96	σ
V1	207	496	2659	3210	4354	68	182	[e]	283	567	2471	3286	4602	70	127	[e]
V2	223	465	2636	3020	3661	74	172		234	525	2527	3123	4490	66	189	
V3	219	684	1902	2765	4464	75	57		229	583	2359	3182	4437	68	160	
	216	548	2399	2998	4159	72	137	σ	248	558	2452	3197	4509	68	158	σ
V1	88	604	1682	3163	4299	66	124	[ɛ]	218	653	2152	2976	3670	72	93	[ɛ]
V2	274	596	2256	3226	4425	67	175		237	685	2174	3139	4001	73	115	
V3	171	632	2144	2883	3964	64	94		217	614	2030	2933	3684	67	93	
	177	610	2027	3090	4229	65	131	σ	224	650	2118	3016	3785	70	100	σ
V1	206	920	1691	2785	3673	74	160	[æ]	272	868	1788	2465	3648	75	115	[æ]
V2	81	936	1828	2709	3898	67	157		169	897	1889	3155	4385	58	96	
V3	217	917	1814	2325	3522	75	227		248	865	1841	3032	4074	72	198	
	168	924	1777	2606	3697	72	181	σ	229	876	1839	2884	4035	68	136	σ
V1	178	744	1047	3180	3478	73	151	[ɑ]	187	832	1354	3061	4228	63	157	[ɑ]
V2	181	734	1290	2942	3758	74	199		203	782	1631	3138	4285	68	131	
V3	146	735	1123	2796	3622	68	187		209	839	1526	2585	3819	68	207	
	168	737	1153	2972	3619	71	179	σ	199	817	1503	2928	4110	66	165	σ
V1	174	655	1051	2161	3803	69	85	[ɔ]	212	714	1392	3138	4434	65	56	[ɔ]
V2	188	543	1253	2607	3998	73	294		239	833	1524	3285	4294	69	244	
V3	170	811	1098	2232	3816	71	90		229	634	1329	3375	4389	67	72	
	177	669	1134	2333	3872	71	156	σ	226	727	1415	3266	4372	67	124	σ
V1	181	613	883	3271	3692	68	311	[o]	223	649	1106	3520	4537	73	213	[o]
V2	203	604	1409	2987	4222	71	211		267	549	1506	3284	4393	72	239	
V3	204	736	1224	2692	4048	75	233		202	679	1485	3109	3980	65	163	
	196	651	1172	2983	3987	71	251	σ	230	625	1365	3304	4303	70	205	σ
V1	195	471	1808	2725	4304	71	120	[ʊ]	257	518	1900	3025	4272	69	53	[ʊ]
V2	172	652	1267	2708	4086	69	126		222	622	1545	3153	4530	69	108	
V3	230	473	1360	2825	4091	69	55		264	521	1741	3157	4325	64	74	
	199	532	1478	2752	4160	69	100	σ	247	553	1728	3111	4375	67	78	σ
V1	200	491	1327	2979	4051	69	281	[u]	227	457	1550	3184	4062	69	130	[u]
V2	197	483	839	2962	4424	67	259		268	532	1379	3460	4486	68	174	
V3	198	436	1697	2757	4091	65	329		270	488	1472	3303	4328	67	331	
	198	470	1287	2899	4188	67	289	σ	255	492	1467	3315	4292	68	211	σ
V1	186	605	1275	2661	3931	73	106	[ʌ]	218	676	1622	2608	3777	69	57	[ʌ]
V2	175	816	1555	2904	4127	67	123		215	793	1800	3130	4430	67	133	
V3	205	637	1529	2916	4016	67	49		202	727	1549	3099	4140	63	86	
	188	686	1453	2827	4024	69	92	σ	211	732	1657	2945	4115	66	92	σ

	KSAF13								KSAF14							
	F0	F1	F2	F3	F4	Ints	Dur	IPA	F0	F1	F2	F3	F4	Ints	Dur	IPA
V1	275	482	2649	3092	4274	72	285	[i]	281	483	2418	3080	3947	72	172	[i]
V2	189	397	2122	2981	3855	61	241		179	467	2414	2925	4009	71	327	
V3	215	424	2057	2967	3773	64	108		207	436	2685	3228	4486	74	142	
	226	434	2276	3013	3967	65	211	σ	222	462	2505	3077	4147	72	213	σ
V1	197	543	1456	2625	4204	68	37	[ɪ]	194	546	1475	2802	4233	71	59	[ɪ]
V2	242	535	2208	2446	3415	74	66		231	586	2395	2954	3781	73	104	
V3	219	562	2068	2749	3308	67	73		333	642	2055	3078	4012	71	127	
	219	546	1910	2606	3642	69	58	σ	252	591	1975	2944	4008	71	96	σ
V1	247	536	2263	2891	3812	69	152	[e]	220	522	2572	3146	4101	78	193	[e]
V2	226	480	2216	3090	3437	73	117		228	558	2571	3007	4003	74	157	
V3	210	431	2371	2735	4216	70	78		229	573	2424	2860	4242	73	147	
	227	482	2283	2905	3821	70	115	σ	225	551	2522	3004	4115	75	165	σ
V1	238	724	1556	2940	3808	74	61	[ɛ]	213	733	1908	2517	3707	75	109	[ɛ]
V2	220	666	2318	3045	3646	74	122		220	729	2115	3000	3890	73	130	
V3	203	631	1947	2856	3668	77	49		210	615	2042	2762	3894	78	127	
	220	673	1940	2947	3707	75	77	σ	214	692	2021	2759	3830	75	122	σ
V1	216	988	1485	2621	3558	81	94	[æ]	221	974	1613	2556	3735	75	110	[æ]
V2	203	965	1810	2656	4605	70	238		196	934	1674	2727	3517	76	195	
V3	207	994	1824	2625	3205	75	100		239	952	1645	2674	3914	79	184	
	208	982	1706	2634	3789	75	144	σ	218	953	1644	2652	3722	76	163	σ
V1	173	902	1197	2467	3574	72	129	[ɑ]	175	792	1223	2631	3764	77	273	[ɑ]
V2	214	778	1246	2666	3507	72	138		198	842	1483	2800	3645	79	129	
V3	186	844	1239	2314	3686	75	174		200	904	1386	2572	3339	80	181	
	191	841	1227	2482	3589	73	147	σ	191	846	1364	2667	3582	78	194	σ
V1	202	577	1207	2342	3745	66	48	[ɔ]	140	726	1382	2273	3578	75	128	[ɔ]
V2	186	892	1274	2603	3389	77	189		149	599	1149	2890	4118	72	236	
V3	111	546	1069	2433	3712	65	71		197	796	1385	2361	3469	76	130	
	166	671	1183	2459	3615	69	102	σ	162	707	1305	2508	3721	74	164	σ
V1	194	651	1024	3005	3974	68	205	[o]	199	605	1081	2928	3996	76	268	[o]
V2	246	550	1249	2823	4038	72	295		212	599	1169	2983	4023	78	382	
V3	205	524	1386	2825	4005	67	299		208	584	1323	2512	3541	75	193	
	215	575	1219	2884	4005	69	266	σ	206	596	1191	2807	3853	76	281	σ
V1	229	481	1897	2608	4101	71	62	[ʊ]	206	432	2000	2768	4234	75	90	[ʊ]
V2	142	578	1310	2762	3700	71	78		149	722	1447	2937	4100	74	193	
V3	235	489	1272	2898	4223	65	29		216	435	1878	2807	4494	72	56	
	202	516	1493	2756	4008	69	56	σ	190	529	1775	2837	4276	73	113	σ
V1	215	537	1527	2818	3893	65	143	[u]	210	437	1456	2916	3979	76	303	[u]
V2	252	496	1067	2754	4074	67	86		246	503	1242	2866	4267	74	189	
V3	229	456	1738	2866	3977	68	245		212	434	1501	2643	4076	71	321	
	232	496	1444	2812	3981	66	158	σ	222	458	1399	2808	4107	73	271	σ
V1	226	738	1353	2450	3344	74	45	[ʌ]	218	761	1480	2501	3489	79	111	[ʌ]
V2	212	878	1565	2432	4031	73	130		206	867	1621	2776	3832	75	216	
V3	233	918	1283	2742	3376	74	115		217	870	1606	2441	3846	78	152	
	223	844	1400	2541	3583	73	96	σ	213	832	1569	2572	3722	77	159	σ

	KSAF15								KSAF16							
	F0	F1	F2	F3	F4	Ints	Dur	IPA	F0	F1	F2	F3	F4	Ints	Dur	IPA
V1	304	418	2277	2895	4159	70	164	[i]	297	393	2166	2726	3591	73	113	[i]
V2	225	399	2625	3208	4046	65	173		184	417	2261	2974	3835	61	290	
V3	206	566	2761	3270	4054	63	85		247	435	2617	3184	4012	69	106	
	245	461	2554	3124	4086	66	140	σ	242	415	2348	2961	3812	67	169	σ
V1	188	568	1866	2784	3733	69	31	[ɪ]	210	462	1540	3010	4190	67	53	[ɪ]
V2	229	539	2310	2828	4117	69	52		209	518	2540	3033	4015	72	68	
V3	225	582	2104	2959	4309	66	85		235	607	2173	2637	3434	67	84	
	214	563	2093	2857	4053	68	56	σ	218	529	2084	2893	3879	68	68	σ
V1	285	504	2379	3063	4037	71	139	[e]	214	573	2468	3101	4240	70	105	[e]
V2	230	486	2539	3043	3803	71	111		208	555	2542	3056	4203	69	161	
V3	222	462	2443	2894	4033	70	70		225	876	1984	2892	4268	66	79	
	245	484	2453	3000	3957	70	106	σ	215	668	2331	3016	4237	68	115	σ
V1	204	565	2122	3043	3967	72	77	[ɛ]	209	657	1776	3159	3932	71	36	[ɛ]
V2	390	641	2261	3047	4155	68	127		228	678	2267	2793	3478	71	169	
V3	199	575	1857	2675	3287	70	54		205	672	1915	2793	3612	67	95	
	264	593	2080	2921	3803	70	86	σ	214	669	1986	2915	3674	69	100	σ
V1	230	892	1653	2719	3791	70	144	[æ]	225	1012	1759	2722	3592	71	119	[æ]
V2	78	835	1758	2631	3364	65	138		98	945	1783	2466	3812	59	91	
V3	220	961	1756	2370	3427	71	124		217	1056	1845	2449	3671	71	170	
	176	896	1722	2573	3527	68	135	σ	180	1004	1795	2545	3691	67	126	σ
V1	517	778	1247	2578	3337	69	57	[ɑ]	180	830	1314	2754	4128	72	112	[ɑ]
V2	188	729	1452	2738	3681	76	79		197	818	1474	2817	3729	69	116	
V3	233	776	1388	2757	3355	74	130		196	799	1331	2758	3752	72	118	
	312	761	1362	2691	3457	73	88	σ	191	815	1373	2776	3869	71	115	σ
V1	191	606	1348	2392	3582	71	83	[ɔ]	212	684	1402	2142	3807	73	45	[ɔ]
V2	255	555	1352	2956	4038	70	209		236	600	1181	3197	4212	74	177	
V3	167	653	1315	2313	3517	69	74		205	648	1339	2045	3637	74	121	
	204	604	1338	2553	3712	70	122	σ	217	644	1307	2461	3885	73	114	σ
V1	213	627	1072	3184	3589	70	201	[o]	273	662	1109	3235	4016	71	169	[o]
V2	196	581	1265	2834	3858	69	158		257	544	1331	3250	4248	75	169	
V3	208	637	1527	2793	3713	70	142		203	578	1603	3031	3969	70	185	
	205	615	1288	2937	3720	69	167	σ	244	594	1347	3172	4077	72	174	σ
V1	256	513	1991	2799	4027	69	55	[ʊ]	232	459	1844	3087	3993	72	77	[ʊ]
V2	259	631	1444	2931	3929	72	98		254	523	1549	2977	4327	68	120	
V3	210	474	1278	2891	4090	67	33		234	1167	2440	3409	4261	64	29	
	241	539	1571	2873	4015	69	62	σ	240	716	1944	3157	4193	68	75	σ
V1	184	412	1665	2761	3703	65	129	[u]	207	421	1850	2725	3748	62	192	[u]
V2	273	429	1372	2825	4048	69	79		280	496	1358	3111	4312	71	109	
V3	228	521	1633	2842	3888	67	251		218	437	1920	2888	3803	67	219	
	228	454	1556	2809	3879	67	153	σ	235	451	1709	2908	3954	66	173	σ
V1	215	681	1401	2225	3354	72	68	[ʌ]	213	680	1387	2377	3500	73	99	[ʌ]
V2	244	826	1500	2769	3309	71	91		242	848	1798	2827	4274	69	129	
V3	237	760	1502	2529	3639	74	55		217	883	1542	2623	3806	73	82	
	232	755	1467	2507	3434	72	71	σ	224	803	1575	2609	3860	71	103	σ

	KSAF17							KSAF18							
	F0	F1	F2	F3	F4	Ints	Dur	F0	F1	F2	F3	F4	Ints	Dur	IPA
V1	382	418	2209	2767	3520	75	134	277	499	2484	3216	4387	67	189	[i]
V2	196	376	2510	3040	3852	63	168	198	415	2673	3303	4264	64	244	[i]
V3	232	458	2634	3170	3570	72	116	222	490	2620	3080	4224	66	123	[i]
	270	417	2451	2992	3647	70	139	232	468	2592	3199	4291	65	185	σ
V1	241	496	1862	2992	4362	73	31	198	504	1978	2865	4271	66	34	[ɪ]
V2	285	575	2505	2845	3174	76	54	249	503	2479	2971	3839	70	84	[ɪ]
V3	402	583	2226	2936	3484	74	86	217	497	2313	3023	4154	67	92	[ɪ]
	309	551	2197	2924	3673	74	57	221	501	2256	2953	4088	67	70	σ
V1	289	468	2228	3137	3915	72	146	228	548	2646	3230	4306	69	150	[e]
V2	286	628	2269	2839	3648	78	95	237	517	2444	2879	3830	66	176	[e]
V3	254	537	2368	3049	3935	74	113	218	452	2485	2955	3714	64	118	[e]
	276	544	2288	3008	3832	74	118	227	505	2525	3021	3950	66	148	σ
V1	247	732	1724	3322	4042	71	47	202	656	1587	2652	3282	72	57	[ɛ]
V2	313	711	2211	2772	3448	79	73	226	665	2186	2865	3756	71	131	[ɛ]
V3	185	651	2247	2978	4090	71	76	198	651	1974	2794	3694	69	77	[ɛ]
	248	698	2060	3024	3860	73	65	208	657	1915	2770	3577	70	88	σ
V1	190	844	1718	2439	3172	76	111	228	813	1721	2851	3823	71	121	[æ]
V2	75	907	1871	2824	3726	70	126	151	808	1766	2992	3935	62	159	[æ]
V3	205	1041	1722	2476	3209	78	186	240	816	1743	2832	3825	71	215	[æ]
	156	930	1770	2579	3369	74	141	206	812	1743	2891	3861	68	165	σ
V1	438	866	1278	2785	3850	76	110	188	752	1245	2739	3765	69	225	[ɑ]
V2	194	696	1325	3136	3740	77	129	207	670	1425	2791	3929	71	121	[ɑ]
V3	125	802	1249	2922	3521	76	150	188	755	1365	2576	3720	71	167	[ɑ]
	252	788	1284	2947	3703	76	129	194	725	1345	2702	3804	70	171	σ
V1	104	670	1223	2457	3313	74	80	207	596	1244	2093	3390	65	76	[ɔ]
V2	224	518	2077	2755	3780	74	306	197	779	1329	2908	3701	70	218	[ɔ]
V3	707	764	1350	2520	3270	76	54	210	636	1151	2881	4033	71	59	[ɔ]
	345	650	1550	2577	3454	74	146	204	670	1241	2627	3708	68	117	σ
V1	242	624	934	3346	3838	76	217	196	619	962	3179	3802	67	212	[o]
V2	264	574	1081	3233	4074	78	370	233	619	1173	2777	4072	72	220	[o]
V3	186	592	1166	3101	3756	78	146	216	599	1352	2825	3989	70	148	[o]
	230	596	1060	3226	3889	77	244	215	612	1162	2927	3954	69	193	σ
V1	222	477	1888	2779	4109	75	58	212	437	1824	2713	4119	70	49	[ʊ]
V2	205	531	1271	3240	4243	75	96	184	595	1327	2901	3991	68	123	[ʊ]
V3	300	476	1565	2964	4302	72	55	253	496	1221	2757	4083	66	45	[ʊ]
	242	494	1574	2994	4218	74	69	216	509	1457	2790	4064	68	72	σ
V1	278	432	1700	2886	3723	69	165	222	451	1573	2969	4023	66	154	[u]
V2	252	531	1119	3085	4006	70	100	272	458	1184	2884	4239	66	121	[u]
V3	304	463	1278	2841	3809	72	318	211	463	1384	2888	4197	65	246	[u]
	278	475	1365	2937	3846	70	194	235	457	1380	2913	4153	65	173	σ
V1	206	804	1434	2994	3663	78	51	216	673	1442	2570	3610	74	50	[ʌ]
V2	75	809	1681	2963	3722	76	101	197	742	1751	2823	4062	72	134	[ʌ]
V3	224	789	1432	2346	3360	74	85	238	706	1538	2879	4009	69	96	[ʌ]
	168	800	1515	2767	3581	76	79	217	707	1577	2757	3893	71	93	σ

KSAF19	F0	F1	F2	F3	F4	Ints	Dur	IPA
V1	204	557	1888	3173	3667	74	82	[i]
V2	274	646	2082	3048	4014	77	146	
V3	238	499	2046	3037	3770	79	57	
	238	567	2005	3086	3817	76	95	σ
V1	219	577	2392	2956	3857	74	145	[ɪ]
V2	216	454	2550	3158	3930	73	124	
V3	200	479	2265	2728	3894	75	121	
	211	503	2402	2947	3893	74	130	σ
V1	246	468	2480	3156	4148	69	222	[e]
V2	169	375	2512	3188	4138	66	186	
V3	247	556	2628	3187	4210	70	121	
	220	466	2540	3177	4165	68	176	σ
V1	207	472	1674	2855	3921	74	100	[ɛ]
V2	176	699	1094	2884	3859	80	171	
V3	219	463	1306	2968	4018	69	47	
	200	544	1358	2902	3932	74	106	σ
V1	186	650	1018	3312	4011	76	271	[æ]
V2	227	573	1135	3111	3942	77	170	
V3	201	700	1312	2479	3479	73	186	
	204	641	1155	2967	3810	75	209	σ
V1	211	443	1309	3099	3671	71	148	[ɑ]
V2	229	474	1121	3083	3938	72	75	
V3	201	404	1208	2918	3802	68	222	
	213	440	1212	3033	3803	70	148	σ
V1	172	480	1652	2906	4034	71	50	[ɔ]
V2	218	497	2400	3045	4344	71	64	
V3	212	532	2129	3114	4390	72	75	
	200	503	2060	3021	4256	71	63	σ
V1	155	794	1152	2771	3813	79	111	[o]
V2	177	796	1450	2669	3878	78	213	
V3	175	780	1422	2632	3660	77	182	
	169	790	1341	2690	3783	78	168	σ
V1	218	685	1314	2733	3499	81	55	[ʊ]
V2	182	767	1524	2947	3865	78	161	
V3	188	721	1455	3107	4030	75	70	
	196	724	1431	2929	3798	78	95	σ
V1	172	660	1201	2572	3428	72	66	[u]
V2	179	866	1386	2769	4006	78	234	
V3	184	693	1150	2806	3686	76	72	
	178	739	1245	2715	3706	75	124	σ
V1	215	901	1643	2938	4077	78	110	[ʌ]
V2	84	843	1797	2884	4145	73	115	
V3	244	851	1677	3195	4092	80	255	
	181	865	1705	3005	4104	77	160	σ

KSAF20	F0	F1	F2	F3	F4	Ints	Dur	IPA
V1	163	612	2048	2909	4343	70	88	[i]
V2	192	607	2151	2954	4078	69	97	
V3	91	585	2079	2703	3746	69	54	
	148	601	2092	2855	4055	69	79	σ
V1	199	474	2609	3050	4450	68	157	[ɪ]
V2	211	488	2502	3031	4358	69	148	
V3	188	410	2495	2906	4493	67	104	
	199	457	2535	2995	4433	68	136	σ
V1	260	470	2650	3168	4673	69	204	[e]
V2	222	437	2647	3091	4585	64	300	
V3	197	432	2656	3083	4611	67	142	
	226	446	2651	3114	4623	66	215	σ
V1	187	466	1917	2820	4343	68	91	[ɛ]
V2	227	622	1154	2643	3973	71	110	
V3	198	489	1218	2713	4201	66	41	
	204	525	1429	2725	4172	68	80	σ
V1	85	720	1050	2916	3675	63	132	[æ]
V2	204	697	1017	2505	3862	73	171	
V3	166	701	1224	2865	3717	70	180	
	151	706	1097	2762	3751	68	161	σ
V1	191	401	1644	2781	3725	66	243	[ɑ]
V2	231	476	1050	2711	4345	70	123	
V3	217	496	1346	2765	3875	68	202	
	213	457	1346	2752	3981	68	189	σ
V1	178	541	1652	2638	4367	70	38	[ɔ]
V2	75	558	2383	2898	4478	63	71	
V3	193	471	2153	3111	4518	65	75	
	148	523	2062	2882	4454	66	61	σ
V1	169	764	1104	2726	3758	72	131	[o]
V2	188	766	1387	2816	3994	72	113	
V3	181	735	1380	2496	3754	70	216	
	179	755	1290	2679	3835	71	153	σ
V1	194	764	1401	2508	3678	77	61	[ʊ]
V2	223	766	1525	2622	3988	74	108	
V3	183	700	1438	2980	4159	69	63	
	200	743	1454	2703	3941	73	77	σ
V1	75	774	1231	2481	3672	66	71	[u]
V2	196	528	974	2799	3920	70	274	
V3	178	680	1188	2405	3641	68	103	
	149	660	1131	2561	3744	68	149	σ
V1	217	190	1559	2890	4434	73	163	[ʌ]
V2	222	766	1715	2900	4136	72	197	
V3	216	877	1651	3131	4160	73	237	
	218	611	1641	2973	4243	72	199	σ

	KSAF21								KSAF22							
	F0	F1	F2	F3	F4	Ints	Dur	IPA	F0	F1	F2	F3	F4	Ints	Dur	IPA
V1	257	403	2426	3007	3912	69	129	[i]	296	401	2426	3083	4271	72	149	[i]
V2	180	404	2735	3305	4515	67	178		104	407	2676	3238	4169	62	178	
V3	227	453	2602	3149	4600	69	94		232	464	2817	3528	4215	69	125	
	221	420	2587	3153	4342	68	133	σ	210	424	2639	3283	4218	67	150	σ
V1	205	531	1773	3082	4030	67	32	[ɪ]	197	553	1464	3040	4314	69	31	[ɪ]
V2	276	511	2413	3136	4556	69	38		109	509	2271	2965	4315	72	62	
V3	243	547	1906	3341	4686	72	49		248	492	1975	3141	4170	71	37	
	241	529	2030	3186	4424	69	39	σ	184	518	1903	3048	4266	70	43	σ
V1	229	466	2460	3150	4295	72	102	[e]	234	490	2422	3167	4149	73	122	[e]
V2	225	508	2383	3045	4219	73	78		204	510	2497	3210	4028	75	175	
V3	225	457	2448	3014	4182	73	84		195	771	1643	2196	4155	74	71	
	226	477	2430	3069	4232	72	88	σ	211	590	2187	2857	4110	74	122	σ
V1	224	578	1846	3223	4457	74	67	[ɛ]	216	622	1820	3199	4345	74	62	[ɛ]
V2	219	723	1986	3141	4144	78	121		203	666	2101	3003	3972	78	141	
V3	214	652	1896	2656	3819	78	69		199	649	1871	3016	3840	76	83	
	219	651	1909	3006	4140	76	85	σ	206	645	1930	3072	4052	76	95	σ
V1	108	814	1628	2685	3448	76	92	[æ]	247	793	1387	3133	4040	76	120	[æ]
V2	75	884	1684	2949	3910	69	119		212	827	1747	2839	4076	72	164	
V3	241	864	1674	3079	3887	75	135		213	961	1707	2587	3773	78	248	
	141	854	1662	2904	3748	73	115	σ	224	860	1613	2853	3963	75	177	σ
V1	75	809	1218	2838	3490	72	154	[ɑ]	177	853	1207	3206	3789	76	145	[ɑ]
V2	208	689	1553	3035	3909	76	82		195	608	1210	2887	4061	78	77	
V3	194	673	1327	2524	3756	74	112		195	670	1297	2634	3697	75	176	
	159	723	1366	2799	3718	74	116	σ	189	710	1238	2909	3849	76	132	σ
V1	106	633	1435	2224	3747	70	50	[ɔ]	185	605	1369	2883	4046	71	56	[ɔ]
V2	155	763	1452	2944	3884	78	232		187	513	934	3019	4112	72	176	
V3	102	610	1100	2260	3534	69	53		191	595	1032	2784	4198	75	68	
	121	668	1329	2476	3721	72	111	σ	187	571	1111	2895	4118	72	100	σ
V1	136	570	897	3396	3560	73	108	[o]	277	585	1106	3305	4139	74	296	[o]
V2	249	583	1331	2909	4187	79	121		271	577	1386	3180	4382	76	329	
V3	228	554	1432	2622	3751	72	153		196	503	1655	2671	4096	71	299	
	204	569	1220	2975	3832	74	127	σ	248	555	1382	3052	4205	73	308	σ
V1	237	487	1732	3153	4126	73	62	[ʊ]	227	477	2119	2819	3956	72	83	[ʊ]
V2	93	654	1345	2622	4084	71	79		206	533	1468	2838	4154	74	134	
V3	263	487	1740	2919	4230	65	18		215	479	1625	2713	4203	72	42	
	197	542	1605	2898	4146	69	53	σ	216	496	1737	2790	4104	72	86	σ
V1	212	416	1461	2957	3852	68	145	[u]	210	538	1760	2943	3828	71	164	[u]
V2	258	543	1016	2950	4305	74	69		253	520	1426	2849	4175	77	155	
V3	194	440	1504	2718	3892	70	218		273	517	1736	2846	4121	74	338	
	221	466	1327	2875	4016	70	144	σ	245	525	1640	2879	4041	74	219	σ
V1	218	568	1343	2332	3761	74	99	[ʌ]	210	629	1254	2732	3526	80	89	[ʌ]
V2	127	743	1499	2974	4039	76	89		193	720	1450	2911	3914	76	124	
V3	263	771	1633	2789	4045	74	58		237	687	1502	2944	3981	77	165	
	202	694	1491	2698	3948	74	82	σ	213	678	1402	2862	3807	77	126	σ

KSAF23								
	F0	**F1**	**F2**	**F3**	**F4**	**Ints**	**Dur**	**IPA**
V1	312	535	2379	2852	3815	69	314	[i]
V2	233	430	2459	3088	3718	64	250	
V3	238	470	2746	3281	4322	68	93	
	261	478	2528	3073	3951	67	219	σ
V1	200	523	1700	3149	4462	66	26	[ɪ]
V2	233	528	2249	3017	4079	70	57	
V3	200	505	1989	2986	4329	70	157	
	211	518	1979	3050	4290	68	80	σ
V1	249	570	2060	2826	3774	72	223	[e]
V2	253	563	2418	3175	4214	70	206	
V3	252	506	2614	3208	4369	69	127	
	251	546	2364	3069	4119	70	185	σ
V1	210	657	1833	2877	4014	71	112	[ɛ]
V2	260	748	1937	2872	3959	75	133	
V3	217	737	1761	2611	3809	70	69	
	229	714	1843	2786	3927	72	104	σ
V1	247	913	1633	2357	3554	76	181	[æ]
V2	223	831	1641	2585	3392	71	165	
V3	270	903	1618	2604	3402	71	244	
	246	882	1630	2515	3449	72	196	σ
V1	209	863	1310	2905	4091	72	218	[ɑ]
V2	241	785	1439	2786	3924	72	228	
V3	245	801	1297	2480	3641	75	114	
	231	816	1348	2723	3885	73	186	σ
V1	222	655	1491	2573	4387	67	82	[ɔ]
V2	219	869	1424	2971	3791	72	246	
V3	204	699	1083	2626	3990	67	75	
	215	741	1332	2723	4056	68	134	σ
V1	228	746	1169	3272	3871	70	234	[o]
V2	265	752	1252	3173	3959	76	136	
V3	205	717	1334	2696	3640	70	188	
	232	738	1251	3047	3823	72	186	σ
V1	242	522	1727	3058	4565	71	113	[ʊ]
V2	245	661	1313	2958	4388	72	83	
V3	242	480	1612	3122	4638	70	54	
	243	554	1550	3046	4530	71	83	σ
V1	221	451	1625	3107	4123	69	164	[u]
V2	278	490	1169	3289	4589	69	147	
V3	239	488	1259	3203	4084	68	369	
	246	476	1351	3199	4265	68	226	σ
V1	240	763	1573	2802	4186	77	63	[ʌ]
V2	232	810	1571	2548	3472	73	126	
V3	269	794	1564	2537	3914	73	99	
	247	789	1569	2629	3857	74	96	σ

Appendix J: All Male SSE Measurements for 7 Correlates

Vowel sound and name										
fleece	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**foot**	**goose**	**strut**
[i]	[ɪ]	[e]*	[ɛ]	[æ]	[ɑ]	[ɔ]	[o]*	[ʊ]	[u]	[ʌ]
V1: please V2: peas V3: meet	V1: with V2: thick V3: is	V1: maybe V2: faked V3: paper	V1: yellow V2: edge V3: red	V1: ask V2: pad V3: mat	V1: Bob V2: dog V3: frog	V1: for V2: bought V3: corner	V1: old V2: go V3: zone	V1: good V2: book V3: cookie	V1: blue V2: scoop V3: zoo	V1: rubber V2: duck V3: must

	KSAM1								KSAM2							
	F0	**F1**	**F2**	**F3**	**F4**	**Ints**	**Dur**	**IPA**	**F0**	**F1**	**F2**	**F3**	**F4**	**Ints**	**Dur**	**IPA**
V1	144	414	2067	2541	4013	78	147	[i]	162	385	2140	2619	3917	78	214	[i]
V2	142	419	2005	2521	3589	67	144		124	386	2139	2622	4023	63	281	
V3	129	357	2302	2810	3976	74	131		118	519	2238	2694	3923	71	98	
	138	396	2124	2624	3859	73	140	σ	134	430	2172	2645	3954	70	197	σ
V1	122	854	1624	2734	3849	64	127	[ɪ]	122	513	1471	2449	3676	70	43	[ɪ]
V2	113	507	1949	2509	3718	73	130		139	576	1991	2706	3848	77	62	
V3	107	499	1721	2493	3812	68	130		157	489	1863	2542	3736	78	80	
	114	620	1764	2578	3793	68	129	σ	139	526	1775	2565	3753	75	61	σ
V1	124	508	2072	2676	3960	76	228	[e]	125	541	2073	2719	3685	72	74	[e]
V2	128	508	2084	2667	4014	77	147		167	449	2205	2670	3841	76	116	
V3	122	490	1817	2483	3265	76	124		124	459	2165	2556	3574	72	93	
	124	502	1991	2608	3746	76	166	σ	138	483	2147	2648	3700	73	94	σ
V1	118	561	1488	2597	4226	78	122	[ɛ]	118	611	1765	2712	3833	77	77	[ɛ]
V2	211	581	1988	2612	3869	76	219		123	547	1931	2558	3703	73	188	
V3	117	512	1749	2582	3741	78	63		161	517	1780	2566	3705	76	73	
	148	551	1741	2597	3945	77	134	σ	134	558	1825	2612	3747	75	112	σ
V1	122	720	1425	2459	4319	78	96	[æ]	483	832	1497	2526	3554	80	174	[æ]
V2	663	671	1627	2389	4069	78	92		757	729	1661	2594	3741	67	154	
V3	125	715	1415	2222	3949	77	152		142	876	1613	2701	3612	79	176	
	303	702	1489	2356	4112	77	113	σ	460	812	1590	2607	3635	75	168	σ
V1	96	719	1078	2653	4356	79	127	[ɑ]	772	775	1067	2619	3650	75	124	[ɑ]
V2	113	676	1347	2395	4494	78	142		174	721	1210	2592	3631	80	123	
V3	113	545	986	2260	3531	71	104		123	732	1199	2359	3428	78	163	
	107	646	1137	2436	4127	76	124	σ	356	742	1158	2523	3569	77	136	σ
V1	111	576	1046	2385	3240	76	92	[ɔ]	75	650	1151	2639	3773	67	43	[ɔ]
V2	103	736	1088	2548	4322	73	138		120	737	1123	2560	3418	77	154	
V3	121	615	1200	2338	3865	76	105		108	624	1039	2435	3642	71	74	
	111	642	1111	2423	3809	75	111	σ	101	670	1104	2544	3611	71	90	σ
V1	119	565	926	2557	4028	75	450	[o]	127	633	824	2782	3482	78	131	[o]
V2	117	507	1191	2766	3890	74	165		136	668	1487	2663	3873	80	151	
V3	121	694	1950	2670	4480	72	260		171	657	1371	2629	3765	77	282	
	119	588	1355	2664	4132	73	291	σ	144	652	1227	2691	3706	78	188	σ
V1	124	505	1247	2541	3828	76	68	[ʊ]	120	489	1640	2410	3574	73	125	[ʊ]
V2	108	512	916	2780	4096	76	134		119	586	1281	2435	3847	77	114	
V3	124	608	1168	2771	3962	70	77		135	446	1499	2435	3649	71	36	
	118	541	1110	2697	3962	74	93	σ	124	507	1473	2426	3690	73	91	σ
V1	120	524	912	2815	3453	73	140	[u]	75	413	1345	2570	3992	64	74	[u]
V2	135	479	847	2841	3696	72	258		169	440	1339	2463	4008	76	117	
V3	148	477	1017	2781	3733	72	410		125	525	1329	2516	4061	69	330	
	134	493	925	2812	3627	72	269	σ	123	459	1337	2516	4020	69	173	σ
V1	121	674	1341	2421	2768	76	82	[ʌ]	118	734	1140	2612	3345	78	46	[ʌ]
V2	103	658	1295	2355	4245	78	158		115	645	1425	2540	3651	78	143	
V3	124	805	1153	2380	4074	78	82		195	696	1314	2534	3410	79	53	
	116	712	1263	2385	3695	77	107	σ	142	691	1293	2562	3468	78	80	σ

	KSAM3								KSAM4							
	F0	F1	F2	F3	F4	Ints	Dur	IPA	F0	F1	F2	F3	F4	Ints	Dur	IPA
V1	161	403	2318	2772	3565	77	191		153	361	2110	2751	3861	71	175	
V2	124	348	2461	2856	3513	71	181	[i]	108	554	2256	2827	3957	63	146	[i]
V3	152	425	2450	2897	3549	75	93		109	445	2066	2664	3873	66	90	
	145	392	2409	2841	3542	74	155	σ	123	453	2144	2747	3897	66	137	σ
V1	114	509	1560	2679	3456	72	54		113	460	1377	2690	3842	69	36	
V2	138	435	2152	2731	3362	76	75	[ɪ]	130	417	2172	2923	3827	72	100	[ɪ]
V3	154	501	1792	2813	3686	72	77		116	577	1857	2909	473	63	71	
	135	481	1834	2741	3501	73	68	σ	119	484	1802	2840	2714	68	69	σ
V1	146	470	2171	2736	3416	76	121		119	462	2122	2730	3853	69	154	
V2	162	470	2164	2777	3486	78	135	[e]	138	416	2325	2864	4283	73	128	[e]
V3	151	477	1885	2619	3382	76	104		133	446	1957	2530	3830	72	101	
	153	472	2073	2710	3428	76	120	σ	130	441	2134	2708	3988	71	127	σ
V1	150	581	1608	2756	3626	76	66		134	408	1990	2968	3722	76	100	
V2	182	520	1984	2775	3625	78	133	[ɛ]	144	469	2332	2762	3887	73	127	[ɛ]
V3	128	509	1835	2640	3372	76	61		116	466	1855	2468	3418	74	70	
	153	536	1809	2723	3541	76	86	σ	131	447	2059	2732	3675	74	99	σ
V1	176	766	1605	2698	3595	79	112		114	761	1551	2558	3338	67	135	
V2	590	666	1721	2677	3463	74	116	[æ]	625	624	1876	2658	3499	69	113	[æ]
V3	174	705	1619	2937	3588	77	166		118	749	1642	2365	3539	71	155	
	313	712	1648	2770	3548	76	131	σ	285	711	1689	2527	3458	69	134	σ
V1	296	746	1200	2756	3354	77	106		92	573	1225	2339	3518	71	79	
V2	127	686	1322	2789	3414	80	117	[ɑ]	123	592	1354	2621	3734	76	154	[ɑ]
V3	123	642	1201	2476	3517	77	166		113	557	1154	2164	3691	78	135	
	182	691	1241	2673	3428	78	129	σ	109	574	1244	2374	3647	75	122	σ
V1	120	639	1142	2350	3117	74	81		117	540	1136	2639	3412	73	118	
V2	136	680	1174	2790	3156	80	154	[ɔ]	102	489	1286	2713	3915	70	179	[ɔ]
V3	116	666	1256	2429	3036	77	100		112	585	1147	2236	3603	73	71	
	124	661	1190	2523	3103	77	111	σ	110	538	1189	2529	3643	72	122	σ
V1	136	689	838	3036	3568	76	134		114	604	1309	2992	4323	72	176	
V2	159	586	1163	2580	3410	79	142	[o]	126	537	1352	2679	3902	73	280	[o]
V3	137	629	1234	2597	3421	79	147		133	465	1384	2643	3495	71	118	
	144	634	1078	2737	3466	78	141	σ	124	535	1348	2771	3906	72	191	σ
V1	142	563	1341	2801	3581	75	132		125	404	1663	2453	3726	72	78	
V2	116	648	1076	2905	3578	78	108	[ʊ]	95	553	1272	2423	3534	70	133	[ʊ]
V3	163	512	1249	2642	3492	75	44		457	527	1340	2733	3749	67	38	
	140	574	1222	2782	3550	76	94	σ	225	494	1425	2536	3669	69	83	σ
V1	137	532	1338	2966	3875	71	121		121	568	1813	3014	4105	66	123	
V2	163	442	1103	2710	3542	75	163	[u]	133	328	1554	2580	3861	69	115	[u]
V3	140	605	1406	2813	3676	72	216		137	574	1769	2974	3927	69	310	
	146	526	1282	2829	3697	72	166	σ	130	490	1712	2856	3964	68	182	σ
V1	145	644	1077	2511	3261	78	83		131	581	1271	1921	3571	78	84	
V2	174	643	1451	2748	3605	80	134	[ʌ]	188	636	1499	2357	3588	69	103	[ʌ]
V3	189	736	1400	2809	3743	79	78		123	752	1093	2653	3304	68	128	
	169	674	1309	2689	3536	79	98	σ	147	656	1287	2310	3487	71	105	σ

KSAM5

	F0	F1	F2	F3	F4	Ints	Dur	IPA
V1	215	449	2347	3105	3880	73	174	[i]
V2	160	538	2553	3322	3961	70	188	
V3	149	482	2482	3069	3780	70	60	
	174	489	2460	3165	3873	71	140	σ
V1	135	435	1362	3151	3836	72	36	[ɪ]
V2	148	484	2142	2976	3859	77	140	
V3	152	485	1700	2986	3838	74	68	
	145	468	1734	3037	3844	74	81	σ
V1	159	488	2198	3043	3954	76	204	[e]
V2	207	505	2343	3036	3806	77	282	
V3	158	480	2109	2754	3828	74	141	
	174	491	2216	2944	3862	75	209	σ
V1	139	456	2510	3466	4037	74	132	[ɛ]
V2	211	623	2082	2922	3753	81	233	
V3	153	619	1779	2429	3674	82	205	
	167	566	2123	2939	3821	79	190	σ
V1	184	786	1406	2857	3618	80	82	[æ]
V2	117	681	1774	2755	3777	78	211	
V3	172	695	1486	2721	3608	80	255	
	157	720	1555	2777	3667	79	182	σ
V1	122	710	1103	2691	3487	81	158	[ɑ]
V2	151	760	1219	2698	3501	81	102	
V3	135	675	1254	2395	3521	78	245	
	136	715	1192	2594	3503	80	168	σ
V1	126	598	1215	1976	3386	77	90	[ɔ]
V2	131	688	1145	2670	3623	80	166	
V3	135	654	1068	2591	3426	81	98	
	130	646	1142	2412	3478	79	118	σ
V1	156	610	961	3222	3672	80	381	[o]
V2	184	530	1183	2957	3799	80	316	
V3	195	464	1436	3014	3779	82	340	
	178	534	1193	3064	3750	80	345	σ
V1	159	514	1428	2951	3716	81	118	[ʊ]
V2	142	622	1140	2744	3638	80	161	
V3	207	422	1825	2887	3915	72	71	
	169	519	1464	2860	3756	77	116	σ
V1	163	487	1205	3064	3804	76	194	[u]
V2	185	422	1469	2949	3817	74	198	
V3	198	475	1481	2932	3795	79	310	
	182	461	1385	2981	3805	76	234	σ
V1	154	634	1116	2630	3368	80	60	[ʌ]
V2	139	733	1344	2659	3560	80	188	
V3	205	639	1133	2987	3582	83	94	
	166	668	1197	2758	3503	81	114	σ

KSAM6

	F0	F1	F2	F3	F4	Ints	Dur	IPA
V1	225	500	2052	2641	3704	77	282	[i]
V2	206	471	2250	2809	3711	72	200	
V3	233	492	2335	2694	3632	81	159	
	221	487	2212	2714	3682	76	213	σ
V1	134	458	1475	2169	3524	78	40	[ɪ]
V2	165	507	1806	2345	3584	77	68	
V3	220	542	1960	2809	3794	74	107	
	173	502	1747	2441	3634	76	71	σ
V1	215	482	2134	2666	3668	81	215	[e]
V2	229	640	1975	2548	3693	83	110	
V3	188	595	1356	2525	3549	81	94	
	210	572	1821	2579	3636	81	139	σ
V1	205	687	1662	2531	4051	83	110	[ɛ]
V2	189	634	2089	2532	3734	81	190	
V3	214	471	1889	2449	3722	81	103	
	202	597	1880	2504	3835	81	134	σ
V1	196	787	1359	2579	4202	82	131	[æ]
V2	174	760	1669	2381	3540	78	145	
V3	208	906	1479	2555	4075	81	281	
	192	817	1502	2505	3939	80	185	σ
V1	157	816	1096	2545	3684	81	152	[ɑ]
V2	186	722	1282	2429	3877	81	104	
V3	171	874	1344	2280	3723	81	181	
	171	804	1240	2418	3761	81	145	σ
V1	117	620	1111	2520	3773	79	76	[ɔ]
V2	181	762	1039	2625	3699	80	173	
V3	183	740	1160	2540	3652	82	163	
	160	707	1103	2561	3708	80	137	σ
V1	207	770	995	2973	4046	82	240	[o]
V2	233	624	1234	2892	3794	80	404	
V3	267	610	1254	2595	3630	82	283	
	235	668	1161	2820	3823	81	309	σ
V1	189	598	1170	2593	3884	82	68	[ʊ]
V2	205	693	1142	2774	3730	82	173	
V3	245	704	917	2784	3853	81	66	
	213	665	1076	2717	3822	81	102	σ
V1	169	498	1387	2871	3806	77	185	[u]
V2	280	607	932	2701	3610	80	304	
V3	239	571	1282	2582	3742	78	275	
	229	558	1200	2718	3719	78	254	σ
V1	133	722	1222	2242	3711	83	73	[ʌ]
V2	150	876	1359	2389	3968	81	97	
V3	191	827	1193	2458	3619	83	105	
	158	808	1258	2363	3766	82	91	σ

	KSAM7								KSAM8							
	F0	F1	F2	F3	F4	Ints	Dur	IPA	F0	F1	F2	F3	F4	Ints	Dur	IPA
V1	172	496	2053	2581	4285	79	134	[i]	171	361	2425	3031	3805	70	238	[i]
V2	122	291	2129	2825	4390	72	259		140	357	2451	3101	3838	69	174	
V3	145	496	2194	2530	4349	78	92		143	345	2395	2938	3699	75	131	
	146	427	2125	2645	4341	76	161	σ	151	354	2423	3023	3780	71	181	σ
V1	114	904	1871	2839	4167	75	31	[ɪ]	129	474	1836	2702	3792	74	71	[ɪ]
V2	148	482	1811	2354	4080	80	109		158	482	2164	2614	3607	78	97	
V3	166	634	1967	2732	4416	78	78		140	435	2105	2807	3875	73	104	
	142	673	1883	2641	4221	77	72	σ	142	463	2035	2707	3758	75	90	σ
V1	173	577	2055	2495	4068	79	152	[e]	186	463	2351	2822	3663	75	149	[e]
V2	122	470	1923	2413	4310	79	257		137	470	2295	2982	3880	75	168	
V3	126	591	1754	2387	4105	79	124		162	501	2059	2688	3626	78	141	
	140	546	1910	2431	4161	79	177	σ	161	478	2235	2830	3723	76	152	σ
V1	148	624	1617	2477	4060	82	108	[ɛ]	143	594	1430	2786	3641	80	100	[ɛ]
V2	281	571	1749	2478	4196	79	219		254	546	2087	2784	3816	78	213	
V3	131	419	1868	2378	3982	78	102		126	524	2008	2563	3581	75	113	
	186	538	1744	2444	4079	79	143	σ	174	554	1841	2711	3679	77	142	σ
V1	143	784	1231	2714	4020	81	137	[æ]	144	757	1581	2775	3645	78	179	[æ]
V2	441	747	1554	2462	4069	77	179		367	692	1753	2634	3767	77	82	
V3	170	850	1498	2756	3802	80	225		185	759	1623	2472	3503	78	245	
	251	793	1427	2644	3963	79	180	σ	232	736	1652	2627	3638	77	168	σ
V1	111	739	1139	2549	4126	80	100	[ɑ]	244	714	1136	2924	3600	82	110	[ɑ]
V2	546	659	1203	2282	4038	80	150		119	654	1200	2816	3517	76	178	
V3	122	713	1166	2409	3847	81	188		122	635	1006	2557	3649	75	169	
	259	703	1169	2413	4003	80	146	σ	161	667	1114	2765	3588	77	152	σ
V1	120	706	932	2430	4137	79	169	[ɔ]	145	625	975	2730	3416	81	258	[ɔ]
V2	308	745	1169	2462	3973	80	212		128	635	867	2861	3407	77	232	
V3	342	666	1106	2157	3963	81	131		143	608	1157	2615	3568	81	97	
	256	705	1069	2349	4024	80	170	σ	138	622	999	2735	3463	79	195	σ
V1	148	497	1041	2675	4170	79	432	[o]	196	616	802	3069	3625	80	303	[o]
V2	120	628	958	2441	4060	79	325		179	528	1025	2882	3660	79	381	
V3	140	908	2228	2714	4349	79	198		129	650	1453	2769	3677	71	234	
	136	677	1409	2610	4193	79	318	σ	168	598	1093	2906	3654	76	306	σ
V1	147	484	1397	2196	4022	81	138	[ʊ]	146	426	1441	2603	3606	73	148	[ʊ]
V2	125	557	1216	2296	4180	77	222		126	493	1274	3012	3668	71	124	
V3	157	744	1769	3142	4410	76	44		127	703	1024	2583	3647	63	94	
	143	595	1460	2544	4204	78	134	σ	133	540	1246	2732	3640	69	122	σ
V1	128	624	1470	2602	4454	77	336	[u]	158	355	1392	2696	3683	72	152	[u]
V2	96	783	2038	2654	4395	79	223		133	502	1658	3125	3891	69	206	
V3	143	752	1986	3141	4367	78	308		127	578	2061	3291	3919	69	328	
	122	719	1831	2799	4405	78	289	σ	139	478	1703	3037	3831	70	228	σ
V1	148	735	1140	2579	3733	80	90	[ʌ]	159	691	1297	2418	3621	83	92	[ʌ]
V2	125	795	1239	2607	3771	78	208		142	754	1363	2740	3612	80	150	
V3	137	836	1210	2645	4046	82	66		169	759	1351	2555	3699	80	84	
	136	788	1196	2610	3850	80	121	σ	156	734	1337	2571	3644	81	108	σ

KSAM9	F0	F1	F2	F3	F4	Ints	Dur	IPA
V1	140	309	2229	2696	3882	73	130	
V2	106	507	2449	2918	4016	74	108	[i]
V3	134	430	2220	2678	3609	70	140	
	126	415	2299	2764	3835	72	126	σ
V1	106	452	1625	2788	3974	71	554	
V2	136	422	2111	2691	3878	75	115	[ɪ]
V3	130	480	1907	2743	3948	72	175	
	124	451	1881	2740	3933	72	281	σ
V1	139	492	2192	2865	3583	72	218	
V2	129	476	2097	2725	3789	74	125	[e]
V3	146	490	1633	2551	3608	77	61	
	138	486	1974	2713	3660	74	134	σ
V1	132	577	1619	2613	3648	80	81	
V2	125	480	2024	2871	4021	72	157	[ɛ]
V3	129	523	1907	2660	3648	76	139	
	128	526	1850	2714	3772	76	125	σ
V1	130	722	1450	2503	3641	77	125	
V2	109	752	1666	2509	3454	72	134	[æ]
V3	138	721	1589	2599	3436	74	235	
	125	731	1568	2537	3510	74	164	σ
V1	488	694	1146	2808	3318	79	96	
V2	129	596	1307	2384	3425	77	141	[ɑ]
V3	138	684	1027	2272	3127	78	118	
	251	658	1160	2488	3290	78	118	σ
V1	116	609	938	2308	3366	73	145	
V2	546	742	1170	2734	3380	77	109	[ɔ]
V3	124	725	1457	2780	3756	76	79	
	262	692	1188	2607	3500	75	111	σ
V1	119	717	1016	2793	3330	78	229	
V2	144	607	1300	2729	3778	76	213	[o]
V3	137	696	1261	2572	3462	75	197	
	133	673	1192	2698	3523	76	213	σ
V1	127	549	1275	2502	3568	80	113	
V2	123	642	1162	2811	3600	79	80	[ʊ]
V3	137	485	2252	3397	4553	71	48	
	129	558	1563	2903	3907	76	80	σ
V1	164	640	2209	3267	4486	69	290	
V2	122	665	2511	3536	4547	71	212	[u]
V3	163	740	2231	3291	4402	70	345	
	149	681	2317	3364	4478	70	282	σ
V1	138	693	1105	2301	3210	80	87	
V2	126	682	1501	2844	3598	80	64	[ʌ]
V3	155	658	1226	2493	3438	72	92	
	139	677	1277	2546	3415	77	81	σ

Appendix K: IRB Approval

ST. CLOUD STATE UNIVERSITY
EDUCATION FOR LIFE.

Institutional Review Board (IRB)

720 4th Avenue South AS 210, St. Cloud, MN 56301-4498

IRB PROTOCOL DETERMINATION:
Exempt Review

Name: Mahdi Duris

Email: mduris@stcloudstate.edu

Project Title: Acoustic Phonetic Analysis of Arabic Native L2 English

Advisor Ettien Koffi

The Institutional Review Board has reviewed your protocol to conduct research involving human subjects. Your project has been: **APPROVED**

Please note the following important information concerning IRB projects:

- The principal investigator assumes the responsibilities for the protection of participants in this project. Any adverse events must be reported to the IRB as soon as possible (ex. research related injuries, harmful outcomes, significant withdrawal of subject population, etc.).

- For expedited or full board review, the principal investigator must submit a Continuing Review/Final Report form in advance of the expiration date indicated on this letter to report conclusion of the research or request an extension.

-Exempt review only requires the submission of a Continuing Review/Final Report form in advance of the expiration date indicated in this letter if an extension of time is needed.

- Approved consent forms display the official IRB stamp which documents approval and expiration dates. If a renewal is requested and approved, new consent forms will be officially stamped and reflect the new approval and expiration dates.

- The principal investigator must seek approval for any changes to the study (ex. research design, consent process, survey/interview instruments, funding source, etc.). The IRB reserves the right to review the research at any time.

If we can be of further assistance, feel free to contact the IRB at 320-308-4932 or email ResearchNow@stcloudstate.edu and please reference the SCSU IRB number when corresponding.

IRB Chair:

Dr. Benjamin Witts
Associate Professor- Applied Behavior Analysis
Department of Community Psychology, Counseling, and Family Therapy

IRB Institutional Official:

Dr. Latha Ramakrishnan
Interim Associate Provost for Research
Dean of Graduate Studies

OFFICE USE ONLY

SCSU IRB# 1905 - 2447	**Type:** Exempt Review	**Today's Date:** 5/1/2019
1st Year Approval Date: 4/23/2019	**2nd Year Approval Date:**	**3rd Year Approval Date:**
1st Year Expiration Date:	**2nd Year Expiration Date:**	**3rd Year Expiration Date:**

Appendix L: Letter of Consent

Acoustic Phonetic Analysis of L1 and L2 Englishes
Informed Consent

Invitation: I, Mahdi Duris, Graduate student of Linguistics at Saint Cloud State University, am inviting you to participate in a study of how English varies among native speakers and non-native speakers. This study examines the pronunciation of English by Native Arabic speakers. If you choose to participate in this study, you will be recorded or will record yourself reading the words, phrases, sentences, and a short paragraph below.

Purpose: The purpose of the study is to contribute acoustic phonetic knowledge that may help improve the intelligibility of English spoken by Native Arabic speakers. You are being asked to read some words, phrases, sentences, and text as naturally as possible.

Time required: The recordings will take approximately 30 minutes of your time.

Procedure: If you agree to participate in this study you will be recorded, or you will record yourself reading the attached text. The reading and the recording will take less than 30 minutes. Some words in the text will to be analyzed acoustically.

Risks: The risks (if any) associated with this study are not greater than the risk of talking or reading aloud in everyday life.

Benefits: An anticipated benefit of this type of acoustic phonetics is to improve the intelligibility of Arabic accented English.

Confidentiality: Your names will not appear in the analyses. Your names will not appear in any report or publication based on these recordings. The words that you say will be converted into numbers through PRAAT phonetic analysis software, so your identity is fully protected.

Withdrawal: Your participation is voluntary. You can change your mind anytime if you decide not to participate in this study it is OK. My relationship with you will not be damaged because of it. Also, your relationship with Saint Cloud State University will not be affected by your refusal to participate in this study. If you choose to participate, Thank You!

Research Results: The acoustic data obtained from the recordings an analysis will be available upon the completion of the study should you be interested in learning more about the results or the acoustic phonetic characteristics of your own speech. You can obtain you results by contacting me (mduris@stcloudstate.edu) and/or my advisor Ettien Koffi (enkoffi@stcloudstate.edu).

Age Requirement: You must be at least 18 years of age to participate in this study.

Contact: You may contact me at mduris@stcloudstate.edu and/or my advisor Ettien Koffi (enkoffi@stcloudstate.edu) if you have any questions.

Signature: Your signature indicates that you have read the information provided above, and you have consented to participate in this study. You may withdraw from the study at any time without penalty after signing this form.

Date: ________________________ Consent: ______________________________
Sincerely,

Mahdi Duris
Graduate student of Linguistics

Appendix M: Thesis Arabic Title

وضوح نطق الحروف الانجليزية المتحركة لدى السعوديين

مهدي بن جان-لوي دوريس