## University of Basrah



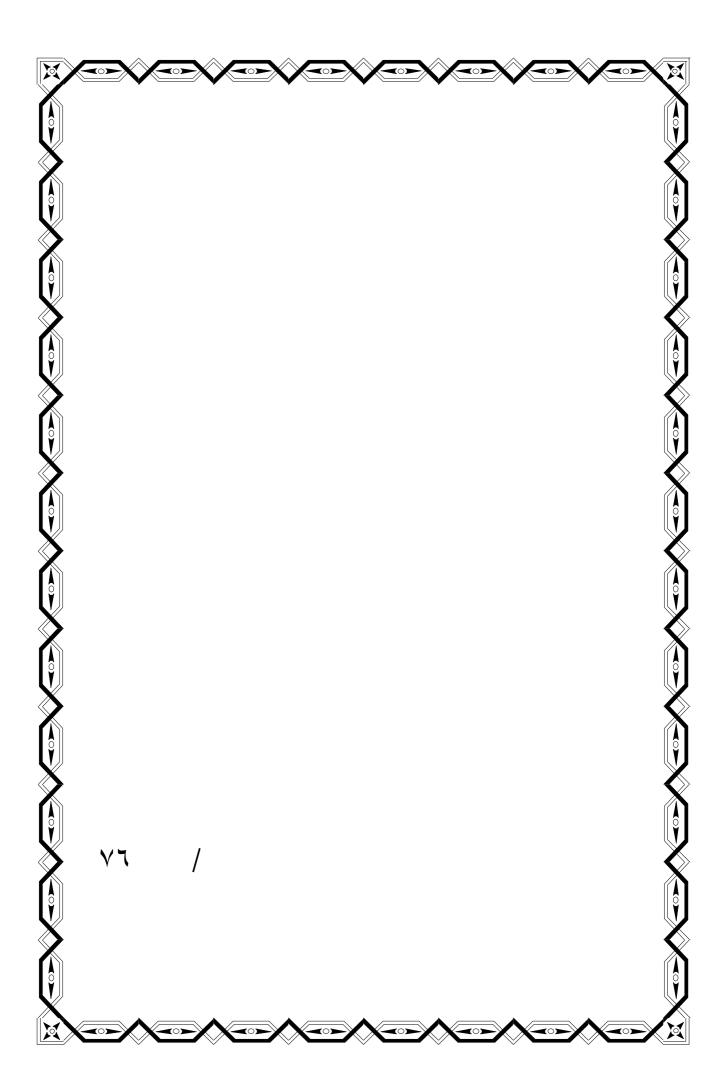
# Evidence of Temporal Compensation in the Syllable Structure of Modern Standard Arabic: An Acoustic Investigation

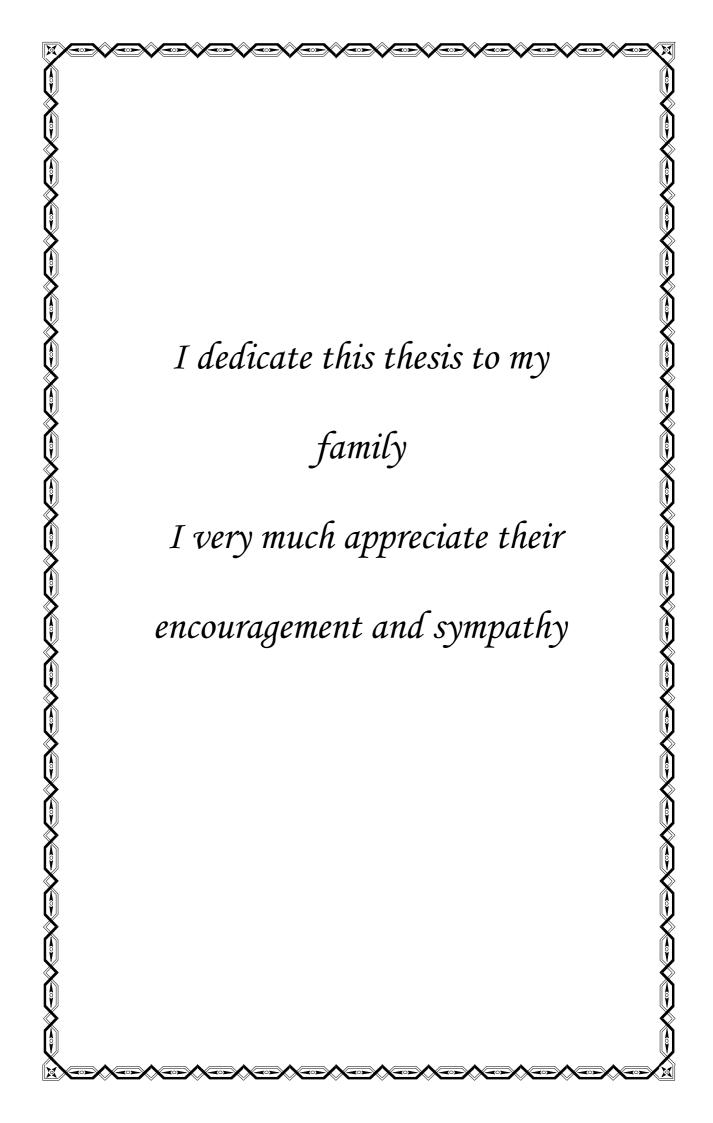
A Thesis Submitted to the Council of the College of Arts the University of Basrah in Partial Fulfillment of the Requirements for the Degree of Master of Arts in Applied Linguistics

> By Najwa Salim Yousif

Supervised By Prof. Dr. Ghalib B. M. Ghalib

August/2005





### Certification

I certify that this thesis was prepared under my supervision at the University of Basrah as a partial requirement for the degree of Master of Arts in Applied Linguistics.

Signature: JBM Shally

Supervisor's Name: Prof. Dr. Ghalib B. M. Ghalib

Date:

In view of the available recommendations, I forward this thesis for debate by the examining committee.

Signature: Adipmality

Name: Assist. Prof. Dr. Adll M. Khanfar

Head of the Department of English

Date:

### Committee's Report

We certify that we have read this thesis, and as an examining committee, examined the student in its content, and in our opinion it is adequate as a thesis for the degree of Master of Arts in Applied Linguistics.

Signature: Ma Lea A Scaly Signature:

Name: Prof. Dr. Mohammed J. Buti

Name: Assist, Prof. Dr. Ala'a H. Odah

Ala. Ap. Oda

(member)

The 25th of Sept 12005

Signature: H.M.HAMA

Name: Assist. Prof. Hamid M. Al-Hamadi

(member)

Name: Prof. Dr. Ghalib B. M/Ghalib

(supervisor)

Approved by the council of the College of Arts.

Signature:

Name: Dr. Basim Hattab Attu mah

Dean of the College of Arts

Date:

# **CONTENTS**

Title Contents	<b>Page</b> i
Acknowledgements	v
Abstract	vii
List of Phonetic Symbols	ix
List of Tables	xiv
List of Figures	.xviii
Abbreviations and Other Symbols	XX
CHAPTER ONE: Preliminaries	
1.1 Introduction	1
1.2 Problem	2
1.3 Hypotheses	2
1.4 Aims of the Study	2
1.5 Scope of the Study	3
1.6 Significance of the Study	3
1.7 Procedure	3
1.8 Definitions of Basic Terms	4
1.8.1 Modern Standard Arabic	4
1.8.2 Spectrogram	4
1.8.3 Acoustic Phonetics	5
1.8.4 Speech Filing System	5
CHAPTER TWO: The Phonological System and the Word	
Structure in Arabic: A Brief Consideration	
2.1 Introduction	6
2.2 The Phonological System in Arabic:	
A Historical Background	6

2.2.1 The Arabic Vowels 8
2.2.2 The Arabic Consonants9
2.3 The Syllable
2.4 The Syllable Structure in MSA13
2.5 Stress
2.6 Stress Patterns in MSA16
2.7 The Morphological Analysis
of the Word in Arabic18
2.7.1 Analogy19
2.7.2 Derivation
2.7.3 Compounding22
CHAPTER THREE: Previous Studies on Segmental Duration and
Temporal Compensation: A General Survey
3.1 Introduction
3.1 Introduction
3.2 Review of Literature25
3.2 Review of Literature

3.5 The Phenomenon of Temporal
Compensation52
CHAPTER FOUR: The Experimental Design
4.1 Introduction61
4.2 Method62
4.2.1 Selection and Categorization of Data62
4.2.1.1 Category I63
4.2.1.2 Category II64
4.2.1.3 Category III65
4.2.1.4 Category IV65
4.2.2 The Subjects68
4.2.3 The Recording Technique and
Instrumental Set-Up68
4.2.4 The Computer Software
Package69
4.2.5 Segmentation and Measurement70
CHAPTER FIVE: Results, Discussion, Conclusions and Suggestions
for Future Research
5.1 Introduction91
5.2 The Statistical Treatment91
5.3 Results95
5.3.1 The Mean Durations of Voiceless and
Voiced Single Versus Geminate
Consonants95
5.3.2 The Mean Durations of Vowel /a/ Before
Voiceless and Voiced Single Versus
Geminate Consonants98

5.3.3 The Mean Durations of Vowel /a/ After
Voiceless and Voiced Single Versus
Geminate Consonants100
5.3.4 The Mean Durations of Vowel /a/ Before
/-CCa-/-Sequences Versus /-CCaa-/-
Sequences
5.3.5 The Mean Durations of Vowel /a/ After
/-aC-/-Sequences Versus /-aaC-/-
Sequences
5.4 Discussion of Results
5.4.1 The Durational Contrasts of Single Versus Geminate Consonants
Durations
5.4.3 The Preceding Vowel Duration
Followed by /-CCa-/- Sequences
Versus /-CCaa-/-Sequences145
5.4.4 The Following Vowel Preceded
by /-aC-/- Sequences Versus
/-aaC-/-Sequences146
5.5 Conclusions
5.6 Suggestions for Future Research149
Appendix-A
Appendix-B158
Appendix-C165
Bibliography166
Abstract (in Arabic)

# <u>Acknowledgements</u>

I would like to express my deepest gratitude to my supervisor Prof. Dr. Ghalib B.M. Ghalib for suggesting the topic of this thesis. I am deeply indebted to him for his excellent guidance and valuable and beneficial comments in addition to his patience and readiness at all times to help me complete this research.

I am also indebted to Prof. Dr. ShihabA. Al-Nasir for his kindness in translating the thesis title into Arabic. I am also indebted to Miss Sahirah A. Dawood, Mr. Abdul-Kareem T. Abdul-Wahhab and Mr. Ala`a Q. Chillab for providing me with the basic references and computer softwares needed for accomplishing this project. I wish to register special thanks to Dr. As`ad Y. Aiyed for his enormous support for carrying out the statistical analysis.

Further, I would like to thank Dr. Awatif Attamimi, Mr. Nasir S. Gatta (Dept. of Arabic/College of Arts) and Dr. Saleemah Jabbar (Dept. of Arabic/College of Education) for revising the stimulus items employed in performing the recordings in addition to checking the thesis title and Abstract in Arabic. Thanks are also extended to Duleim M. Al-Qahtani (Jubail Industrial College), Mark Huckvale, Volker Dellwo (University College London), and James M. Scobbie (Queen Margaret

University College) for sending me useful research papers. Special thanks are also forwarded to the people participated in the recording sessions. I do appreciate their help and patience they expressed when reading the wordlists.

Special thanks are sincerely presented to my family and all my friends for their assistance and encouragement throughout this study.

Thanks are also dedicated to all staff of the central library, the library at the Dept. of English/College of Arts, and the library of the College of Education for the facilitations they offered me to get the required sources. Last but not least, I wish to express my sincere gratitude to the University of Basrah for granting me the opportunity to accomplish this research.

### **Abstract**

The study of temporal compensation phenomenon helps uncover the temporal model that may characterize the Arabic phonological sounds as compared to those of the other languages.

This research is conducted to experimentally validate the existence of temporal compensation phenomenon in Modern Standard Arabic syllable structures. In fact, it is an experimental study divided into five chapters. Chapter one is an introductory chapter to the study as a whole. It underlines the main question of the study concerning the existence of temporal compensation process in Modern Standard Arabic. In addition, it exposes the hypotheses to be tested, the scope, aims and significance of the study. Besides, it presents an outline of the experimental procedure which is followed by the researcher to carry out the experimental part of the research.

Chapter two exhibits a brief theoretical background of the phonological system in Modern Standard Arabic in addition to an explanation of the basic syllable and stress patterns. Moreover, it yields the most essential word formation processes whereby new lexical items are created. Chapter three represents a detailed review of the previous studies that have dealt with segmental duration and the factors via which it is affected as well as the studies that have inspected the timing compensation mechanism in Arabic and in other languages as well.

Chapter four explicates the experimental design. It displays the procedure adopted to choose and categorize the data and the recording technique. It also describes the computer software manipulated to perform the experiment. Furthermore, it explains the procedure followed to segment the obtained spectrograms in order to extract the required acoustic measurements. Chapter five includes the results and the statistical analysis to

which they are subjected in addition to a systematic interpretation of the results. It also presents the final conclusions deduced on the basis of the measurements drawn from the spectrographic pictures accompanied by waveforms. Additionally, it introduces several suggestions that may be of considerable benefit for researchers in the same domain in future.

Finally, the thesis ends with three appendices and a bibliography containing the references consulted throughout this study.

### List of Phonetic Symbols

The following are the phonetic symbols used in the transcriptions of the speech samples in addition to the examples used in the present study.

### A. The English Phonetic Symbols

### 1. Consonants<sup>1</sup>:

Symbol	Example	Phonemic Transcription
/p/	pad	/'pæd/
/b/	bat	/'bæt/
/ <b>t</b> /	tip	/ <b>'t1p</b> /
/ <b>d</b> /	door	/'dɔ:/
/k/	kick	/ <b>'k</b> Ik/
/g/	gun	/ <b>'g∧n</b> /
/ <b>f</b> /	far	/ <b>'fa:</b> /
/v/	vague	/'veig/
/ 0 /	think	/'01ŋk/
/ð/	this	/'ðis/
/s/	sea	/¹si:/
/ <b>z</b> /	zone	/ˈzəʊn/
/ʃ/	sheet	/ <b>'</b> ʃi:t/
/3/	visual	/¹vɪʒʊəl/

/ <b>h</b> /	heart	/ <b>'ha:t</b> /
/ <b>t</b> ∫/	change	/'t∫eIndʒ/
/d <b>3</b> /	judge	/ <b>'d3^d3</b> /
/m/	man	/'mæn/
/n/	nun	/ <b>'n∧n</b> /
/ŋ/	sing	/ <b>'sIŋ</b> /
/r/	read	/'ri:d/
/1/	lead	/ˈli:d/
/w/	well	/'wel/
/ <b>j</b> /	you	/ <b>'ju:</b> /

# $1. \underline{\text{Vowels}}^{1,2}$ :

Symbol	Example	Phonemic Transcription
/1/	hit	/'hɪt/
/ <b>i:</b> /	heat	/ <b>'hi:t</b> /
/ <b>e</b> /	bed	/'bed/
/ <b>æ</b> /	bad	/'bæd/
/a:/	arm	/'a:m/
/ט/	got	/ˈgɒt/
/ɔ:/	saw	/ <b>'</b> sɔ:/
/ʊ/	could	/ <b>'kʊd</b> /
/ <b>u:</b> /	too	/ <b>'tu:</b> /
/ <b>/</b> /	cup	/ <b>'k∧p</b> /
/ <b>ə</b> /	about	/əˈbaʊt/

<sup>1.</sup> After Roach,1991

<sup>2. 9</sup>L+ phonetic notation system is used for English vowels transcription.

/3:/	fur	/ <b>'f</b> 3ː/
/ <b>eI</b> /	page	/ <b>'peId3</b> /
/a <b>I</b> /	five	/'faIv/
/ <b>JI</b> /	join	/'dʒɔɪn/
/əʊ/	home	/ˈhəʊm/
/aʊ/	now	/'naʊ/
/ <b>I</b> ə/	near	/ <b>'n1</b> ə/
/eə/	hair	/'heə/
/ʊə/	pure	/ˈpjʊə/

# **B.** The Arabic Phonetic Symbols:

# 1. Consonants<sup>3</sup>:

Symbol	Example	English Equivalent	Phonemic Transcription
/ <b>b</b> /	باب	door	/¹baab/
/t/	تمر	dates	/'tamr/
/ţ/	طب	medicine	/ <b>'ţib</b> /
/ <b>d</b> /	درس	lesson	/'dars/
/ <b>d</b> /	ضابط	officer	/ˈd̞aabiţ/
/ <b>k</b> /	كتاب	book	/ki¹taab/
/ <b>q</b> /	قلب	heart	/'qalb/
/ʔ/	ارض	earth	/ <b>'?</b> arḍ/
/ <b>f</b> /	فارس	knight	/¹faaris/

/0/	ثمن	price	/ˈθaman/
/ð/	ذهب	gold	/¹ðahab/
/ð/	ظرف	envelope	/ˈðarf/
/s/	سفر	travelling	/'safar/
/ <u>s</u> /	صديق	friend	/ṣaˈdiiq/
/z/	زمن	time	/'zaman/
/ʃ/	شارع	street	/'SaarIS/
/χ/	خبر	news	/'χabar/
\ <b>R</b> \	غريب	strange	/ka'riib/
/ħ/	حوت	whale	/'ħuut/
/5/	عقل	brain	/'Saql/
/ <b>h</b> /	هدف	goal	/'hadaf/
/dʒ/	جدار	wall	/dʒiˈdaar/
/ <b>m</b> /	ملح	salt	/ˈmilħ/
/ n /	نحل	bees	/'naħl/
/r/	ريف	countryside	/'riif/
/1/	لاعب	player	/ˈlaaʕɪb/
/w/	وريد	vein	/wa¹riid/
/ <b>j</b> /	يتيم	orphan	/ja¹tiim/

# 2. $\underline{\text{Vowels}}^{3,4}$ :

Symbol	Example	English Equivalent	Phonemic Transcription
/ <b>i</b> /	من	from	/'min/
/ <b>ii</b> /	عميق	deep	/Sa <sup>1</sup> miiq/
/a/	نهر	river	/'nahr/
/aa/	ساق	leg	/'saaq/
/ <b>u</b> /	<u>قل</u>	say (imp.)	/¹qul/
/uu/	سور	fence	/¹suur/

<sup>3.</sup> After Ghalib,1984.

<sup>4. 2</sup>Lphonetic notation system is used for Arabic vowels transcription.

# **List of Tables**

<u>Ta</u>	<u>ble No.</u>
2.1	The Description of the Arabic vowels
2.2	The classification of the Arabic consonants
2.3	The basic patterns of the syllable structure in MSA14
3.1	The complete set of structures31
3.2	The complete set of structures
3.3	The Korean consonants occurring in onset and coda positions
4.1	The word sets of the patterns / fa\al/~/ fa\al/ included in category I63
4.2	The word sets of the patterns /'fassal/~/fas'saal/ included in category II64
4.3	The word sets of the patterns /'fa\fal/~/'faa\fal/ included in category III65
4.4	The word sets of the patterns /'faa\al/~/fa\sistal/ included in category IV66
4.5	The word sets of the first group
4.6	The word sets of the second group67
4.7	The word sets of the third group
5.1	The mean durations of voiceless single vs. geminate consonants pronounced
	in words of the patterns / $fa$ al/~/ $fa$ al/ produced in isolation
5.2	The mean durations of voiceless single vs. geminate consonants pronounced
	in words of the patterns /'fa\fal/~/'fa\fal/ produced in context111
5.3	The mean durations of voiced single vs. geminate consonants pronounced
	in words of the patterns / $fa$ al/~/ $fa$ al/ produced in isolation
5.4	The mean durations of voiced single vs. geminate consonants pronounced
	in words of the patterns /'fa\fal/~/'fa\fal/ produced in context
5.5	The mean durations of vowel /a/ before voiceless single vs. geminate consonants
	pronounced in words of the patterns / fa\al/~/ fa\al/ produced in isolation
5.6	The mean durations of vowel /a/ before voiceless single vs. geminate consonants
	pronounced in words of the patterns /'fa\fal/~/'fa\fal/ produced in context
5.7	The mean durations of vowel /a/ before voiced single vs. geminate consonants
	pronounced in words of the patterns /'fa\fal/~/'fa\fal/ produced in isolation
5.8	The mean durations of vowel /a/ before voiced single vs. geminate consonants
	pronounced in words of the patterns /'fa\al/~/'fa\al/ produced in context

5.9	The mean durations of vowel /a/ after voiceless single vs. geminate consonants
	pronounced in words of the patterns /'fa\fal/~/'fa\fal/ produced in isolation
5.10	The mean durations of vowel /a/ after voiceless single vs. geminate consonants
	pronounced in words of the patterns /'fa\fa\fa\/al/ produced in context
5.11	The mean durations of vowel /a/ after voiced single vs. geminate consonants
	pronounced in words of the patterns /'fa\fal/~/'fa\fal/ produced in isolation116
5 12	The mean durations of vowel /a/ after voiced single vs. geminate consonants
3.12	pronounced in words of the patterns /'fa\fal/~/'fa\fal/ produced in context116
5.13	The mean durations of the preceding voiceless single consonants and the
3.13	
	following vowel /a/ pronounced in words of the pattern /'fa\al/
5.14	produced in isolation
3.14	
	following vowel /a/ pronounced in words of the pattern / fa al/
5.15	produced in context
3.13	following vowel /a/ pronounced in words of the pattern /'fa\Sal/
	produced in isolation
5.16	
0.110	following vowel /a/ pronounced in words of the pattern / fa\Sal/
	produced in context
5.17	The mean durations of the preceding voiced single consonants and the
	following vowel /a/ pronounced in words of the pattern / fa\al/
	produced in isolation
5.18	The mean durations of the preceding voiced single consonants and the
	following vowel /a/ pronounced in words of the pattern /'fa\al/
	produced in context
5.19	The mean durations of the preceding voiced geminate consonants and the
	following vowel /a/ pronounced in words of the pattern /'fassal/
	produced in isolation
5.20	The mean durations of the preceding voiced geminate consonants and the
	following vowel /a/ pronounced in words of the pattern / fassal/
	produced in context

5.21	The mean durations of the preceding vowel /a/ and the following voiceless geminate consonants /CC/ followed by a short vowel pronounced in words of
	· · · ·
<b>5.00</b>	the pattern / fassal/ produced in isolation
5.22	The mean durations of the preceding vowel /a/ and the following voiceless
	geminate consonants /CC/ followed by a short vowel pronounced in words of
	the pattern / fassal/ produced in context
5.23	The mean durations of the preceding vowel /a/ and the following voiceless
	geminate consonants /CC/ followed by a long vowel pronounced in words of
	the pattern /fas'saal/ produced in isolation
5.24	The mean durations of the preceding vowel /a/ and the following voiceless
	geminate consonants /CC/ followed by a long vowel pronounced in words of
	the pattern /fas'saal/ produced in context
5.25	The mean durations of the preceding vowel /a/ and the following voiced
	geminate consonants /CC/ followed by a short vowel pronounced in words of
	the pattern / fassal/ produced in isolation
5.26	The mean durations of the preceding vowel /a/ and the following voiced
	geminate consonants /CC/ followed by a short vowel pronounced in words of
	the pattern / fassal/ produced in context
5.27	The mean durations of the preceding vowel /a/ and the following voiced
	geminate consonants /CC/ followed by a long vowel pronounced in words of
	the pattern /'fassaal/ produced in isolation
5.28	The mean durations of the preceding vowel /a/ and the following voiced
	geminate consonants /CC/ followed by a long vowel pronounced in words of
	the pattern /fa S'Saal/ produced in context
5.29	The mean durations of the preceding voiceless single consonants /C/ preceded by
	a short vowel and the following vowel /a/ pronounced in words of the pattern
	/'fa\al/ produced in isolation
5.30	The mean durations of the preceding voiceless single consonants /C/ preceded by
	a short vowel and the following vowel /a/ pronounced in words of the
	pattern /'fa\al/ produced in context
5.31	The mean durations of the preceding voiceless single consonants /C/ preceded by
	a long vowel and the following vowel /a/ pronounced in words of the
	nattern /ˈfaaSal/ produced in isolation 126

5.32	The mean durations of the preceding voiceless single consonants /C/ preceded by	
	a long vowel and the following vowel /a/ pronounced in words of the	
	pattern /'faa\al/ produced in context	126
5.33	The mean durations of the preceding voiced single consonants /C/ preceded by	
	a short vowel and the following vowel /a/ pronounced in words of the	
	pattern /'fa\al/ produced in isolation	127
5.34	The mean durations of the preceding voiced single consonants /C/ preceded by	
	a short vowel and the following vowel /a/ pronounced in words of the	
	pattern /'fa\al/ produced in context	127
5.35	The mean durations of the preceding voiced single consonants /C/ preceded by	
	a long vowel and the following vowel /a/ pronounced in words of the	
	pattern /'faa\al/ produced in isolation	128
5.36	The mean durations of the preceding voiced single consonants /C/ preceded by	
	a long vowel and the following vowel /a/ pronounced in words of the	
	pattern /'faaSal/ produced in context	128

# List of Figures

Fig.	No. Page
4.1	A wide-band spectrogram of the word [hɔ:s] 'horse' displaying the arrowheads marking the transitions and the lines extending along the intervening segments.
4.2	The spectrogram and the waveform of the words /'\u03c4\u03c4zan/\\u03c4/'\u03c4\u03c4zan/\\u03c4
4.3	A spectrogram of the words /'fattaħ/~/fat'taaħ/ produced in isolation illustrating the segmental boundaries of the vowels /a/ and /aa/
4.4	A spectrogram of the word /'rad3a\sqrt{-\rangle}'raad3a\sqrt{-\rangle} / produced in isolation illustrating the segmental boundaries of the vowels /a/ and /aa/
4.5	A spectrogram of the words /'hada $\theta$ /~/'hadda $\theta$ / produced in isolation displaying the segmental bounadaries of the plosive /d/ vs. /dd/ occurring medially
4.6	A spectrogram of the words /'hasab/~/'hasab/ produced in isolation displaying the segmental boundaries of the plosive /b/ occurring finally
4.8	displaying the segmental boundaries of the fricative /ʃ/ occurring initially82  A spectrogram of the words /'ħaʃad/~/'ħaʃad/ produced in isolation
1.0	displaying the segmental boundaries of the fricative /ʃ/ vs. /ʃʃ/ occurring medially
4.9	A spectrogram of the words /'naqaʃ/~/'naaqaʃ/ produced in isolation displaying the segmental boundaries of the fricative /ʃ/ occurring finally84
4.10	A spectrogram of the words /'waṣal/~/'waaṣal/ produced in isolation diplaying the segmental boundaries of the fricative /ṣ/ occurring medially
4.11	A spectrogram of the words /'ðakar/~/'ðakkar/ produced in isolation displaying the segmental boundaries of the fricative /ð/ occurring initially

4.12	A spectrogram of the words /'nafað/~/'naffað/ produced in isolation	
	displaying the segmental boundaries of the fricative /ð/ occurring finally	
4.13	A spectrogram of the words /'\fat\tan/~/\fat\'taar/ produced in isolation	
	displaying the segmental boundaries of the flap /r/ occurring finally	88
4.14	A spectrogram of the words /'hamal/~/hammal/ produced in isolation	
	displaying the segmental boundaries of the lateral /l/ occurring finally	89
4.15	A spectrogram of the words /'xazzan/~/xaz'zaan/ produced in isolation	
	displaying the segmental boundaries of the nasal /n/ occurring finally	90
5.1	The durational differences of voiceless single vs. geminate consonants	
	pronounced in words produced in isolation	130
5.2	The durational differences of voiceless single vs. geminate consonants	
	pronounced in words produced in context	131
5.3	The durational differences of voiced single vs. geminate consonants	
	pronounced in words produced in isolation	132
5.4	The durational differences of voiced single vs. geminate consonants	
	pronounced in words produced in context.	133
5.5	The durational differences of vowel /a/ after voiceless single vs. geminate	
	consonants pronounced in words produced in isolation.	138
5.6	The durational differences of vowel /a/ after voiceless single vs. geminate	
	consonants pronounced in words produced in context	139
5.7	The durational differences of vowel /a/ after voiced single vs. geminate	
	consonants pronounced in words produced in isolation	140
5.8	The durational differences of vowel /a/ after voiced single vs. geminate	
	consonants pronounced in words produced in context.	141

# Abbreviations and Other Symbols

Symbol	Description					
ANOVA	Analysis of Variance					
CA	Classical Arabic					
csec.	Centisecond					
db	Decibel					
EPG	Electropalatography					
et al.	and others					
F	F-value of the analysis of variance					
А. Н.	After Higra					
imp.	Imperative					
I.C.Arabic	Iraqi Colloquial Arabic					
Hz	Hertz					
MSA	Modern Standard Arabic					
msec.	Millisecond					
NS	Nonsignificant					
S.D.	Standard Deviation					
SFS	Speech Filing System					
P	Probability					
Т	T-value of the T-Test					
<	Less than					
>	More than					
<u>≤</u>	Equals to or less than					
	Cursor in green signifying a segment onset					
	Cursor in blue signifying a segment offset					
//	Phonemic transcription					
[]	Phonetic transcription					

### **Chapter One**

### **Preliminaries**

### 1.1 Introduction

Temporal compensation, on which this research is based, is a phonetic phenomenon which exists in many different languages, and it is proved to be closely related to segmental duration. It is quite evident that speech sounds vary their own characteristic durations differently. Despite durational variation, the contiguous speech sounds (vowels and consonants) still reveal a 'fixed' and 'predictable' relationship between their durations within the speech sequence where they cluster that they keep durational variation constant (Abercrombie, 1967:81). In other words, under certain conditions the individual sounds alter their durations in a way that keeps the overall duration relatively unchanged.

The duration consistency can be achieved by manner of a compensatory mechanism. That is to say, it involves either lengthening or shortening the durations of certain segments at the expense of others when clustering within a specific speech sequence. This phenomenon can only be experimentally measured; therefore, a series of experimental studies has been conducted to inspect the striking compensatory relationship that dominates the durations of adjacent sounds, i.e. how these sounds affect each other durations.

The present study gives a detailed explanation of the temporal compensation phenomenon in Modern Standard Arabic (MSA for short). Basically, experimental evidence has shown the existence of such a phenomenon between the Arabic phonological segments, i.e. how they compensate for their durational variations in order to maintain durational consistency. The sample data are selected and computerized to produce the spectrographic pictures of the sounds under investigation which are necessary for extracting the acoustic measurements on the time scale (duration).

### 1.2 Problem

Much phonetic research dealing with segmental duration and the compensatory effort exposed by the durations of adjacent segments proved the existence of the temporal compensation phenomenon in the different languages that have been investigated. However, the main problem is that it is claimed that the Arabic language reveals minimal evidence of temporal compensation. Hence, the present research intends to validate the existence of such a phenomenon among the Arabic phonological segments.

### 1.3 Hypotheses

This research hypothesizes that:

- 1. In Arabic, the extra length that characterizes a geminate from its single counterpart is at the expense of the length of the following vowel in the same phonetic context.
- 2. The vowel duration is affected by its position within the word where it is influenced by the phonetic durations of the adjacent segment sequences. Thus, a sequence consisting of a geminate consonant followed by a long vowel affects the duration of the preceding vowel inversely. In the same way, a sequence constituted of a single consonant preceded by a long vowel negatively influences the duration of the following vowel.
- 3. The vowel duration is not influenced by the voicing feature of the adjacent consonant no matter whether it is a single or a geminate consonant.

### 1.4 Aims of the Study

The study aims at accomplishing several objectives. First and above all, it intends to acoustically measure the durations of contiguous vowels and consonants which are elicited from the spectrograms accompanied by waveform graphs.

Second, it aims at measuring and evaluating the timing compensation effort which is revealed by the durational differences of the adjacent vowel and consonant durations (temporal compensation). Finally, it also supports decision-making task as to whether the timing compensatory model exposed by the sample stimulus items under inspection is a characteristic of the Arabic language or it is a universal phenomenon. To put it differently, the present research intends to determine whether timing compensation mechanism in Arabic is a language-specific or a language-universal phenomenon.

### 1.5 Scope of the Study

The research experimentally investigates the interdependent relationship between the durations of adjacent segments and the factors affecting them in the syllable structures of MSA. It also presents a brief discussion of the phonological system and word formation processes related to the language in question.

### 1.6 Significance of the Study

The significance of this study lies in explaining the interesting correlation between vowel and consonant durations; a domain which is of considerable significance for phoneticians and phonologists not only in Arabic but also in many other languages. Since duration is contrastive in Arabic, the present study emphasizes the important role of segmental duration in transmitting information. Besides, it shows that the vowel and consonant durations help distinguish certain classes of phonemes. Moreover, it can be of considerable value for researchers interested in segmental duration differences for the purpose of carrying out further studies in future.

### 1.7 Procedure

A number of steps is followed in order to achieve the aims of this study; these steps are as follows:

- 1. An experiment is designed. It involves choosing data which are extracted from the familiar Arabic lexical items.
- 2. The stimulus items are spoken in isolation and within a carrier sentence by Arabic native speakers. They are recorded via a specific computer software, viz. Speech Filing System (SFS for short).
- 3. A spectrographic analysis of vowel and consonant durations is made. It involves segmenting the spectrograms alongside the waveforms in order to extract the required durational measurements.
- 4. The acoustic measurements are statistically analyzed.
- 5. The results obtained are analyzed to get precise and authentic conclusions.

### 1.8 <u>Definitions of Basic Terms</u>

It seems beneficial to give brief definitions of the following terms.

### 1.8.1 Modern Standard Arabic (MSA)

It is the formal Arabic which is used on television and radio broadcasting, newspapers as well as in educational institutions all over the Arab world. Abboud et al. (1983) contend that MSA is "a universal form of Arabic learned in schools across the Arab world; it is opposed to dialectal or colloquial Arabic." According to them, it is considered as "the direct descendent of the Arabic of the Koran, the poetry of the pre-islamic Arabia, and the classical literature of the Golden Age" (Abboud et al, ibid: 5).

### 1.8.2 Spectrogram

It is a visual representation of a speech sound. It facilitates the acoustic analysis of speech sounds. More specifically, a spectrogram yields "a sort of picture, in

shades of grey or in a variety of colours, of recorded sounds" (Roach, 2002:72).

### 1.8.3 Acoustic Phonetics

It is also known as 'acoustics' or 'physical phonetics'. It is a branch of phonetics which "studies the physical properties of speech sound, as transmitted between mouth and ear. It is wholly dependent on the use of instrumental techniques of investigation, particularly electronics, and some grounding in physics and mathematics is a prerequisite for advanced study of this subject" (Crystal, 1997: 5).

### 1.8.4 Speech Filing System

It is spectrogram-producing computer software employed to create spectrograms accompanied by waveform graphs which stand for the vibratory actions of the vocal folds. It is deemed to be a prerequisite for performing acoustic analysis. It is considered as "a shell program that runs on windows PCs only. It allows the operation of most of the SFS programs by menu selection and dialogues rather than through the command-line" (Huckvale, 2002:1).

### **Chapter Two**

# The Phonological System and the Word Structure in Arabic: A Brief Consideration

### 2.1 Introduction

It is factual that every 'speech chain' is made up of sound sequences (phonemes) which cluster within specific arrangements (syllables) which are constituents of larger units (words) (Malmberg,1963:56). Yet, the arrangements of syllabic units are liable to a set of morphological rules in order to produce meaningful sequences. This definitely reveals the interdependent relationship between the phonological and morphological systems in most languages. Thus, the main goal of the present chapter is to present a brief explanation of the basic aspects related to these two significant systems in the Arabic language.

### 2.2 The Phonological System in Arabic: A Historical Background

The Arab linguists and grammarians have inaugurated the phonetic studies. They were the pioneers to realize the significance of speech sounds; therefore, they achieved many successful investigations of their language sound system (the Arabic sounds). In this respect, Ghalib (1984:1) reports that:

The science of Arabic phonetics is as old as Arabic grammar, and Arabic phonetic studies started simultaneously with Koranic studies. The old Arab grammarians were the first among their people to realize the importance of investigating and studying the various co-existent sounds and sound features in their language.

Thus, the Arab scholars tried to analyze speech sounds in Arabic. For instance, the most well-celebrated grammarian, Al-Farahidi (100-175 A. H.), studied the Arabic

speech sounds and introduced a detailed analysis of them in his famous phonetic dictionary <u>Al-Ain</u> where he classified speech sounds in accordance with their place of articulation. Thus, he divided speech sounds beginning from those produced at the pharynx and ending with those articulated with the lips (Ghalib,op.cit.).

Following his teacher's steps, Sibawaih (135-180 A. H.) continued his search for further phonetic facts (the phonetic investigation). He presented the findings that were obtained in his remarkable masterpiece, namely Al-Kitaab. He divided the Arabic sounds on the basis of two main points. First, Sibawaih meticulously categorized the sounds in Arabic according to their place of articulation into three zones starting from the pharynx, the middle part of the oral cavity, and ending with the lips. Second, he divided the Arabic sounds in terms of the voicing characteristic into voiceless and voiced (Anis,1961:112; and Al-Zaidi,1987:414). For his part, Ghalib (op.cit.:2) remarks that Sibawaih explicated "the Arabic sounds as meticulously as he analyzed the language and for each sound or a group of sounds he indicated a particular place of articulation and gave it a precise description."

Later on, the Arab grammarian, Ibnu Jinni (322-392 A. H.), carried out multiple phonetic studies which were interpreted in his book, Sir Al-Sinaa'ah. He mentioned his observations of the articulation points of the Arabic sounds, and gave a detailed description of them (Al-Mubarak,1970:9). Additionally, it is reported that Ibnu Jinni was the pioneering figure to use the term 'sound' instead of 'letter' which was previously used by his ancestors, namely Al-Khalil and Sibawaihi (Al-Zaidi,op.cit.:426-27). Obviously, this reveals the valuable contribution of the Arab ancient scholars to the present phonetic research. Gairdner (1935:187), as cited by Ghalib (op.cit.:2), contended that the Arab scholars "notably anticipated modern phonetics in their classification of consonants as dental, palatal, velar, etc., and made the most exact observations as to the precise position of the tongue, palate, etc., associated with the production of the several sounds."

Depending on the significant findings of the earlier phonetic investigations, the Arabic speech sounds are classified into two basic categories: vowels and consonants which are discussed in the following two sections.

### 2.2.1 The Arabic Vowels

Generally, a vowel is a sound which is produced without blocking the flow of air. Many phoneticians (e.g. Jones,1956; Gimson,1980; Catford,1988; Roach,1991 and many others) have made attempts to define the vowel both phonetically and phonologically.

From a phonetic perspective, Jones (op.cit.:12) defines the vowel as the sound where "the tongue is held at such a distance from the roof of the mouth that there is no perceptible frictional noise." Ward (1972:65) explains that all vowels are voiced sounds that during the production of which "the air passes through the mouth in a continuous stream, there being no obstruction and no narrowing such as would produce audible friction." In agreement with Ward (ibid), Gimson (op.cit.:32) considers vowels as the sound whose production is devoid of any "closure or narrowing in the speech tract which would prevent the escape of the air stream through the mouth or give rise to audible friction." Roach (op.cit.:10) maintains that "vowels are sounds in which there is no obstruction to the flow of air as it passes from the larynx to lips." Thus, vowels are articulated with "the least obstruction to the flow of air" (Roach, 2002:87).

Phonologically, the vowel sound acts as the centre of the syllabic unit, i.e. it occupies the central position of the syllable (Gimson,op.cit.:32). In this concern, Roach (op.cit.:87) remarks that vowels "are almost always found at the centre of a syllable, and it is rare to find any sound other than a vowel which is able to stand alone as a whole syllable." Arabic, like other languages, has its own vowel system. Mitchell (1993:138), as cited in Newman and Verhoeven (2002:77), states that "the vowel system of Classical Arabic/Modern Standard Arabic is a simple one of three vowel units or phonemes - open, close front, close back - with a superposed short/long distinction applicable to all three." In consequence, the

Arabic vowel system of MSA is basically the same as that of Classical Arabic, i.e. it consists of three short vowels /i, a, u/ as well as their long counterparts (Nasr,1967:39). See table (2.1) for more clarification.

**Table (2.1): The Description of the Arabic Vowels** 

The Symbol	The Description				
/i/	A short close-mid front with lip-spreading vowel.				
/ii/	A long close front with lip spreading vowel.				
/a/	A short open-mid front unrounded vowel.				
/aa/	A long open front unrounded vowel.				
/u/	A short close-mid back rounded vowel.				
/uu/	A long close back rounded vowel.				

After Ghalib (1984).

### 2.2.2 The Arabic Consonants

Phonetically, a consonant is the sound type which is produced either by the flow of air passing through a narrowing in the glottis or by compressing the flow of air behind a closure and, then, is suddenly released (Jones,op.cit.:12; Gimson,op.cit.). Elsewhere, Roach (2002:16) contends that consonants are produced by blocking the stream of air at certain points that the flow of air is impeded to different degrees. He also adds that some types of consonants "do this a lot, some not very much." Accordingly, plosives form the 'maximum obstruction', whereas approximants show 'so little obstruction' to the flow of air. The other consonants come midway between these two extremes. That is to say, plosive consonants are followed by nasals, fricatives and laterals, respectively.

With respect to Arabic, there are (28) consonants which are parallel to the Arabic alphabetic letters. They can occur either as single or geminate consonants. For instance, the /l/-sound in /Salim/ 'knew' is single, whereas it is geminate in

/Sallam/ 'taught' (Abu-Sharifah et al.,1990:14). To come closer to the point, the Arabic consonants are classified in accordance with their place of articulation, into bilabial /b, m/, labio-dental /f/, labio-velar /w/, interdental /θ, ð, ð/, denti-alveolar /t,  $\dot{t}$ , d,  $\dot{d}$ , s,  $\dot{s}$ , z, n/, alveolar /l,r,/, plato-alveolar / $\int$ , d $\dot{z}$ /, palatal / $\dot{z}$ /, velar / $\dot{k}$ /, uvular /q, χ, κ/, pharyngeal /ħ, γ/, and glottal /ʔ, h/ (Al-Zaidi,op.cit.:455). Arabic consonants can also be classified, in accordance with manner of articulation, into plosives /b, t,  $\xi$ , d,  $\varphi$ , k, q,  $\gamma$ ; fricatives /f,  $\theta$ ,  $\delta$ ,  $\delta$ , s,  $\xi$ , z,  $\int$ ,  $\chi$ ,  $\kappa$ ,  $\hbar$ ,  $\gamma$ , h/; affricate /dʒ/; nasals /m, n/; flap /r/; lateral /l/; and approximants /w,j/. Moreover, the Arabic consonants can be further divided, in terms of the voicing feature, into 'voiced' and /mahmuusah/ 'voiceless'. Al-Ani (1978:103) /madzhuurah/ distinguishes between these two types. He states that the /mad3huurah/ sounds are described as "voiced, lenis, pressed, non-breathed and sonorous." Contrary to that, the /mahmuusah/ sounds are described as "voiceless, fortis, non-pressed, breathed and muffled." This denotes that a voiced consonant is produced when the flow of air passes throughout a narrowing in the glottis causing the vocal folds to vibrate, whereas a voiceless consonant is articulated when the flow of air is expelled out of the glottis without bringing about any vibration (Catford, op.cit.:51). Thus, the Arabic voiceless consonants comprise/t,  $\xi$ , k, q, f,  $\theta$ , s,  $\xi$ ,  $\int$ ,  $\chi$ , ħ, h, ?/; while the voiced consonants include /b, d, d, ð, ð, z, **k**, ?, d3, l, m, n, r, w, j/ (Hijazi,1978:45; and Abu-Sharifah et al.,op.cit.:13). See table (2.2) for more illustration. Cowan (1958:3-4) propounds that some Arabic consonants are pronounced in such a way which is approximately similar to that of the English consonants /b, t, d, k, f,  $\theta$ ,  $\delta$ , s, z,  $\int$ , h, dz, m, n, r, l, w, j/. Yet, there are some other Arabic consonants whose pronunciation is considerably distinct. These are called emphatic consonants; they include four emphatic consonants /ţ, d, ŏ, ş/. Phonetically speaking, they are "articulated in the first zone of the oral cavity."

Place of noitelusitre		Plosive	Fricative	Affricate	Nasal	Flap	Lateral	approximant
Isidalia	voiceless	q			E			
-oids.I	voiceless		_		_			
letnab	voiced							7
Labio-velar	voiceless							Ols:
	рээјол							à
Interdental	voiceless		0					
	boolov		ġ Q					
Denti-	voiceless	t t	on.					
alveolar	besiov	ρ́ρ	×					
Alveolar	voiceless							
PROME	basiov					-	-	
-otalaq	voiceless		J					
аврозаја	basiov			4				
Istala	voiceless							
	besiev							-
Velar	voiceless basiov	*						
	voiceless	ь	×					
Uvular	Poiced		20					
	voiceless		-					
Pharyngeal	basiov		~			246		
Istolia	seslesiov	~	4					
	besiev							

Table (2.2): The Classification of the Arabic Consonants

After Ghalib (1984).

The tongue root is carried against the pharynx" (Selouani and Caelen, 2004:2).

It is worth stating that /?/-sound is looked at by some modern Arab linguists as being neither voiced nor voiceless. Instead, it is merely considered as a glottal plosive (Al-Zaidi,op.cit.:455). Gimson (op.cit.:168), for his part, describes the production of /?/ as follows:

...the obstruction to the air-stream is formed by the closure of the vocal folds, thereby interrupting the passage of air into the supra-glottal organs. The air pressure below the glottis is released by the sudden separation of the vocal folds. The compression stage of its articulation consists of silence, its presence being perceived auditorily by the sudden cessation of the preceding sound or by the sudden onset (often with an accompanying strong breath) effort of the following sound.

As a result, the /7/-sound is considered to be a voiceless consonant due to the 'strong air compression' required for its articulation, and its negative effect on the durations of preceding sounds. In agreement with Gimson (ibid:168), Abu-Sharifah et al. (op.cit.) maintain that the /7/-sound is a voiceless glottal plosive.

It is well-known that the Arabic phonemes, whether being consonants or vowels, do not randomly occur as isolated sounds, but they cluster in certain arrangements to form specific units (syllables). That is to say, syllables are made of different structural forms with different stress patterns. The following sections are devoted to present a detailed explanation on this topic.

# 2.3 The Syllable

In every language, the speech chain consists of specific sequences, viz. syllables<sup>1</sup>, which tend to be constituents of larger units (words). Malmberg (op.cit:56) states that:

<sup>1.</sup> For a detailed explanation and discussion of the term 'syllable' from phonetic and phonological viewpoints consult Abercrombie, 1967; Gimson, 1989; and Roach, 2002.

Language is made up of small units which group themselves to form larger and larger units. What we have while listening and what we produce in speaking are chains of sounds -longer or shorter- but always complex and capable of being analyzed into smaller units. Consonants are united with vowels to form syllables.

O'Connor (1973:200) explains that the central part of the syllable is mainly a vowel surrounded by clusters of consonants at the margins. As a corollary, the syllable is larger than the phoneme units which form its structure (O'Connor,ibid:201). In consequence, the syllabic unit can be defined as "a unit of pronunciation typically larger than a single sound and smaller than a word" (Crystal,1997:373). Yet, it has not been easy to establish an adequate definition of this unit, namely syllable.

# 2.4 The Syllable Structure in MSA

In Arabic, syllable structures can be classified into two categories: open and closed syllables. The open syllable refers to the syllable which ends with a vowel, whereas the closed syllable indicates the syllable which ends with a consonant. For instance, the verb /'naqaʃa/ 'he engraved' consists of three open syllables, while the noun /'naqʃun/ 'inscription' is made up of two closed syllables (Ghalib,op.cit.:10). Depending on the distinction between open and closed syllables, Arabic syllable structures can be classified into six basic patterns (Ghalib,ibid:11; Al-Mahfoudh,2000:60). See table (2.3).

These six patterns of the Arabic syllabic structure can be compiled into three main categories: short, medium and long. The short category includes the /CV/ structure. The medium category contains structures of the patterns /CVV/ and /CVC/; whereas the long category comprises /CVVC/, /CVCC/ and /CVVCC/ structures (Ghalib,op.cit.). The short and medium syllable patterns are considered

Table (2.3): The Basic Patterns of the Syllable Structure in MSA

No.	The syllable Structure	Examples	
1	/CV/	/'li/ 'to', /'bi/ 'with'	
2	/CVV/	/'fii/ 'in', /'lii/ 'mine'	
3	/CVC/	/'saf/ 'classroom', /'min/ 'from', /'xaţ / 'line'	
4	/CVCC/	/'dars/ 'lesson', /'nahr/ 'river', /'qalb/ 'heart'	
5	/CVVC/	/'baab/ 'door', /'saaq/ 'leg', /'fiil/ 'elephant'	
6	/CVVCC/	/'haarr/ 'hot', /'saarr/ 'pleasing'	

After Ghalib (1984).

as the most commonly used structures in the Arabic language; they may occur initially or medially, while the long structures are less frequent, i.e. they occur only finally. The word, in Arabic, may include any of the above syllable structure patterns (Ghalib,ibid:12). For example, /jata'qaabal/ 'he meets' consists of four syllables. The first two syllables /ja-/ and /-ta-/ are of the first category; while the other two syllables /-qaa-/ and /-bal-/ are of the second category. Furthermore, it is alleged that the majority of the Arabic words do not comprise more than four syllables. Yet, some other words may consist of more than seven syllables, particularly, when certain affixes are attached to them. For instance, the word /sajuqaabi'luunahumaa/ 'they will meet them' consists of eight syllables.

More to the point, vowels in Arabic never occur initially in a syllable. They must be preceded by one consonant and may be followed by one or two consonants, regardless of their being 'identical' or 'non-identical' (Ghalib,ibid). In this connection, Ghalib (ibid:10) explains that:

Phonologically speaking, a syllable in Classical Arabic is characterized by the fact that it never begins with a vowel, and that the vowel may be preceded by one, and only one, consonant and followed by one or two consonants, whether they are identical or non-identical. The vowel is regarded as the dominant element that determines the number of syllables. Consequently, by counting the number of vowels one can easily and automatically derive the number of syllables in a Classical Arabic word.

However, there are some syllables that are more prominent (stressed) than others. In other words, the prominent syllables are said to be produced with more articulatory effort than that required for producing the less prominent (unstressed) syllables.

# 2.5 <u>Stress</u>

It is believed that syllables within an utterance are not pronounced with the same amount of effort of articulation. This statement is affirmed by Malmberg (op.cit.:80) who states that "in a spoken sentence all the syllables are never produced with the same intensity. Some are weaker (unstressed), others stronger (stressed)." This definitely results in producing syllables which are more prominent (stressed) than others. Abercrombie (1967:35) maintains that the stressed syllable is "produced by a reinforced chest-pulse." And, according to Crystal (op.cit.:363), stress refers to "the degree of force used in producing a syllable." Furthermore, there are two levels of stress: primary and secondary stresses. The less prominent syllable, which can still be described as a stressed one, takes secondary stress. In addition, the syllable which cannot be considered prominent (weak) tends to be unstressed (Roach,1991:87).

It has been found that stress placement depends on the following four essential criteria (Roach ibid:88):

- 1. The morphological structure of the word, i.e. whether it is 'simple', 'complex' or 'compound'.
- 2. The functional category from which the word descends, i.e. whether it is a noun, verb, adjective, etc.

- 3. The number of syllables of which the word is constituted.
- 4. The phonological structure of the syllables of which the word is made up.

Notwithstanding, every language, as in the case of the Arabic language, has its own stress patterns. Hence, it seems beneficial to know the basic Arabic stress patterns.

## 2.6 Stress Patterns in MSA

It is a sheer fact that less attention has been paid by earlier Arab linguists and grammarians to the study of stress. This can be attributed to the fact that they thought that stress does not affect meaning in Arabic (Ken'aan,1977:143; Ghalib,op.cit.:7; and Gatta,1988:42). Nevertheless, some linguists emphasize the considerable role played by word-stress in current Arabic dialects. Thus, many phonetic studies (e.g. Birkeland,1954; Ferguson,1957; Harrel,1957; Nasr,1960 among others) emphasize the existence and significance of stress in Arabic. However, it is argued that word-stress in these dialects "is of minor importance and there is even no decisive evidence as to its significant location in individual words" (Ghalib,1977:52).

For his part, Al-Sa'araan (1962:207), as referred to by Gatta (op.cit.:42), reports that stress in Arabic can be classified into three degrees: primary, secondary and weak. He adds that the manipulation of these three degrees of stress is quite related to the number and type of syllables in a word, i.e. whether they are short, medium or long syllables. In this connection, Omar (1976:308-9) points out that all monosyllabic words have primary stress when uttered in isolation; while polysyllabic words take not only primary but also secondary stress as well. In addition, secondary stress is often placed on the nearest syllable to the initial syllable. As it was previously mentioned, the placement of stress relies on the syllabic structure as well as on the grammatical category of the word itself, i.e. whether it is a verb, noun, article, etc. It also depends on the affixes attached to the word.

In accordance with the number of the syllables a word has, Gatta (op.cit:42-44) contends that stress patterns in Arabic can be classified into the following four types:

- 1. Monosyllabic words usually take primary stress, e.g. /'qiţ/ 'cat', /'naar/ 'fire', /'baab/ 'door', /'tiin/ 'figs', /'riiħ/ 'wind'.
- 2. In the case of disyllabic words, if the second syllable contains a long vowel, it takes primary stress, e.g. /ra'qiib/ 'observer', /na'ʃiiţ/ 'vital', /na'haar/ 'day time'. If the second syllable includes a short vowel, primary stress is placed on the first syllable, e.g. /ˈmudʒhid/ 'exhausting', /ˈkasar/, 'he broke' /ˈqatal/ 'he killed', /ˈʕaalim/ 'scientist', /ˈʃaaʕir/ 'a poet'.
- 3. In trisyllabic words, the final long syllable very often receives primary stress; while, sometimes, it is positioned on the first syllable, e,g, /7ista'faad/ 'he benefited from', /7ista'faar/ 'he brrowed', /'dʒamafa/ 'he collected', /'waaşala/ 'he continued'.
- 4. In the case of words which are made up of more than three syllables, namely 'polysyllabic' words, primary stress is located on the longest syllable before the final one, e.g. /tata'ʃaarak/ 'she shares', /tata'ʃaamal/ 'she deals with'. Yet, primary stress may be placed on the first syllable when the word contains no long syllables, e.g. /'qatalahum/ 'he killed them', /'qatalaahum/ 'he killed them', or on the third syllable counting from the end of the word, e.g. /ta'ʃaaraka/ 'he shared', /ta'saabaqa/ 'he raced with'.

Regarding secondary stress, Gatta (ibid:45) refers that it is often demanded for stylistic purposes as in the case of careful speech and reading. For example, trisyllabic words take secondary stress which often occurs before primary stress. Obviously, it is noticed that the syllable structures and their accompanying stress patterns are correlated with the morphological structure of the word in which they occur (Roach,1983,1991). Thus, it is of considerable importance to shed some light on the process of word formation in Arabic.

# 2.7 The Morphological Analysis of the Word in Arabic

It is self-evident that a word, in most languages, is formed by the juxtaposition of segments within specific sequences in order to convey different meanings. Yet, the combination process is controlled by a set of rules which represent a fundamental prerequisite to word formation; these rules constitute what is called morphology. Hodge (1969:33) contends that "each language is unique not only in its inventory of sounds but also in the manner in which it employs them in meaningful combinations."

In fact, morphology is considered as the basis on which various word forms and structures are formulated (Anis,1966-1967:12; and Abu-Sharifah et al.,op.cit.:18). Thus, morphology comprises a significant division of grammar that can be defined as "the branch of grammar which studies the structure or forms of words, primarily through the use of the morpheme construct" (Crystal,op.cit.:249). As for Allerton (1979:215), he expounds that "the study of the production of new lexical items" represents 'lexical morphology' which is generally labelled 'word-formation'. Thus, lexical morphology functions as a generator of new words by a number of word-formation processes such as derivation and compounding.

Hijazi (op.cit.:55) and Allerton (op.cit.:210) explicate that the Arabic phonemes occur within specific sequences, i.e. roots (most frequently trilateral roots) to which different affixes (prefixes, infixes, and suffixes) are attached to form various word structures. For instance, the root /k-t-b/ can be employed to

formulate forms such as /'kataba/ 'he wrote', /'kaatib/ 'writer', /ki'taab/ 'book', /mak'tuub/ 'written', /kut'taab/ 'writers'/'kutub/ 'books', /kitaa'baat/ 'writings', etc. However, these cognate words share, at least, one common meaning, viz. writing. The derivative nature of the Arabic language as such strikingly distinguishes it from other languages, like English, where, for instance, the root 'go' is entirely different from 'went' (Abu-Sharifah et al., op.cit..:19). Arabic morphology includes several methods via which different word forms are constituted. These methods include: analogy, derivation, compounding, haplology, and arabization. Each method takes on an important role in the course of the developmental stage to which the Arabic language subjects. Nonetheless, the most significant methods are analogy, derivation and compounding (Al-Qazzaz, 1981:240; Al-Zaidi, op.cit.: 272). These methods represent a sign of "vitality and creativeness in the way a language is shaped by the needs of its users" (Yule, 1996:64).

# **2.7.1 Analogy**

It is commonly accepted that language continuously develops its lexical items in order to express miscellaneous ideas. Analogy is one of the basic devices that helps develop the lexical repertory of the Arabic language. Generally, analogy can be defined as a word-formation process "whereby words are formed to be similar in some way to existing words" (Yule,ibid:70). For example, 'yuppie' (a word denoting students protesting the Vietnam war in the United States) was formed by an analogy with 'hippie' that it is first made 'yippie' and then 'yuppie'. In agreement with Yule (ibid), Ali (1987:23), as cited by Al-Sheikhli (1991:72), defines analogy as "the method by which new words are formed or derived in accordance with already existing word patterns." According to Hussein (1960:25), analogy implies generating thousands of well-formed words; besides, it involves grouping or compiling similar word forms into paradigms depending on spoken Classical Arabic versions in addition to developing rules for their formation.

For his part, Al-Qazzaz (op.cit.:294) contends that analogy proves to be quite correlated with the invented linguistic repertoire. Therefore, it is regarded as the most significant linguistic device whose role involves the creation of newly-formulated word forms and structures which denote various meanings. Furthermore, Al-Zaidi (op.cit.:276-78) refers that the invented words in Arabic can be logically classified into four categories as follows:

- 1. The first category includes the word forms which are regular in analogy and use, e.g. /'sabara/ 'he endured' and /'sabran/ 'patiently'.
- 2. The word forms of the second category are regular in use; yet, irregular in analogy, e.g. /'7ista\$\times\text{waba}/ 'he considered it to be correct', /'7ista\times\text{waða}/ 'he captured'.
- 3. The third category includes the word forms which are regular in analogy, but they are irregular in use. For example, /'jaðar/, /'jada\forms which both denote the meaning of 'let'.
- 4. The fourth category contains word forms that are irregular both in analogy and use, e.g. /ma'şuun/ 'be guarded', /ma'quud/ 'be driven'.

In fact, there are multiple analogical forms, such as verbal nouns, present and past participles, and nouns that denote place, time and instrument. The explanation of these forms falls outside the scope of this study<sup>2</sup>.

# 2.7.2 Derivation

Derivation is simply defined as "the process by which derivational affixes are added to stems (including simple roots) to form a derived word" (Allerton, op. cit.:215). Just like analogy, it is an important means that enriches language with new lexical entries, viz. words. Al-Sheikhli (op. cit.:74) maintains that derivation generally means "drawing one word or more from another"

<sup>2.</sup> For further details see Frayha (1953) and Thatcher (1956).

provided that the same order of the root and the general meaning or the idea are kept intact." Moreover, derivation is accomplished by manner of "a large number of small bits" which are not used in dictionaries as separate entries. These are called affixes (Yule,opcit.:69). What is more, it is noticed that affixes fall into three main types: first, prefixes which are positioned at the beginning of a word; second, infixes which are incorporated within a word and third, suffixes by which a word is terminated. In English, for example, the prefixes un-, mis-, pre- are attached to the beginning of the words unhappy, misrepresent, prejudge, whereas the suffixes-ful, -ish, -less are attached to the end of the words joyful, boyish, careless. Infixes are not normally used in English, but they are commonly employed in other languages, such as Kamhmu which is spoken in South East Asia. For instance, the /-rn-/-infix is added to verbs (e.g. see 'to drill' and hiip 'to eat with a spoon') in order to form nouns (e.g. srnee 'drill' and hrniip 'a spoon') (Yule,ibid:69-70).

Closely following Robins (1964:258), Allerton (op.cit.:228) explains that derivational affixes are classified into two categories; 'class maintaining' and 'class changing' affixes which affect the meanings of the lexical items to which they are attached. Yet, it is only the second category which is responsible for influencing the grammatical function of the lexical item. For instance, the English prefix 'semi' is always class maintaining whether it is added to a noun (e.g. semi-circle) or to an adjective (e.g. semi-automatic), whereas the prefixes en-/em-always convert nouns or adjectives into verbs (e.g. enslave, embitter).

In as far as Arabic is concerned, derivation falls into three main types: minor, large (metathesis) and major (replacement) derivations. The first category is considered to be the most significant type because of its effectiveness in expanding the Arabic lexical repertory. The most illustrative example is the word forms derived from the tri-particle root /d-r-b/, as in /'daraba/ 'he hit', /mad'ruub/ 'he is hit', /'darbah/ 'a hit' (Abu-Sharifah et al.,op.cit.:35). Contrary to that, the last two types, viz. the large and major derivations, are not frequently used for forming new words (Al-Sheikhli,ibid:74). For instance, the forms /'dabara/ 'he splinted',

/'burdʒ/ 'tower', /'dʒabr/ 'algebra' are elicited from the tri-particle root /dʒ-b-r/ (Abdul-Tawwab,1973:262-63). It is clear that various forms can be derived from a single root by adding vowels and/or certain affixes (Hodge,op.cit.37).

# 2.7.3 Compounding

A further method of generating word forms in Arabic is compounding. According to Allerton (op.cit.:215) compounding is defined as the process of "combining two stems (either or both of which may be single roots) to give compound words, e.g. mad- + -man, foot- + -ball." Thus, a compound word consists of two free stems which can occur as a word by itself (ibid:216). Yule (op.cit.:65) has maintained that compounding involves the "joining of two separate words to produce a single form." He has referred that a compounding process is a quite productive process that it becomes as the source of so many new words. For example, in English, textbook, wallpaper, doorknob,...,etc.

Linguistically speaking, the term 'compound' refers to "a linguistic unit which is composed of elements that function independently in other circumstances" (Crystal, op. cit.: 78). Similarly, a compound may be defined as "a combination of two or more words so as to function as one word, as a unit" (Jespersen, 1961:134). There exist so many examples of compound words (which descend from different parts of speech) formed by compounding two or more units, viz. 'free morphemes', that can stand by themselves in other conditions; besides, they denote meanings which exceed the essential meanings of the independent constituents of the compound word. For example, telephone-box refers to the boxlike building which is constructed for making telephone calls (Allerton, op. cit.: 210-211). In Arabic, for instance, the compound word /bar'maa?ii/ 'amphibious', which frequently used, consists of two distinct elements, viz. /bar+'maa?ii/ 'land+water' each of which can function meaningfully when occurring as an There are other isolated unit (Ali,op.cit.:81; and Al-Sheikhli,op.cit.:81). combinations in Arabic which are formed by combining the Arabic word

/laa/ 'no' to an adjective or a noun; /laa/ 'no' in such compounds functions in a way similar to that of the English negative affixes a-, in- and -less. For example, /laamarka'zii/ 'acentric', /laa\undersud'wii/ 'inorganic', /laasil'kii/ 'wireless'. It is argued, however, that compounding in Arabic is not a common word-formation process as compared to that in the other languages, like English, and that the use of compounds seems to be limited (Ken`aan,op.cit.:164). She has also claimed that the compounds in Arabic "can be classified into two main categories, namely alnaht (coinage) and altarkeeb (compounding)." Accordingly, the two processes have the same meaning. That is to say, they generate words from two or more roots. Yet, they function differently that "the former is considered as a linguistic process based on contraction or omission of some parts of the roots of which the word is composed; whereas the latter preserves the full form of the roots that constitute a unit known as a 'compound'" (Ken`aan,ibid:164).

Jespersen (op.cit.:135), however, explicates that defining compound words in terms of meaning is unsatisfying. In this respect, he advocates Bloomfieldian's viewpoint which implies that "it is a mistake to use the meaning as a criterion, because we cannot gauge meanings accurately enough." That is to say, a certain phrase may be "as specialized in meaning as any compound." Alternatively, a further resolution is adopted. It is stress which is considered as the best criterion for interpreting compounds in the sense that "wherever we hear lesser or least stress upon a word which would always show stress in a phrase, we describe it as a compound-member." For instance, ice-cream /'aIs,kri:m/ is a compound, but ice-cream /'aIs'kri:m/ is a phrase, though the meaning is kept unchanged. Yet, stress criterion reveals a drawback. It is, sometimes, deemed to be misleading because pronunciation greatly varies from one individual to another. As a result, it becomes difficult to locate the stress. Nevertheless, compounds are increasingly used due to their conciseness, as compared to phrases formed by the usual syntactic rules (Jespersen,op.cit.:137).

# **Chapter Three**

# Previous Studies on Segmental Duration and Temporal compensation: A General Survey

## 3.1 Introduction

It is obvious that each speech segment, whether being a vowel or a consonant, is produced within a certain amount of time. Jones (1967:114) stresses that "speech sounds require time for their utterance, in other words, they have duration or quantity as it is often called." Hence, vowels and consonants have their own characteristic durations. In fact, segmental duration is the most significant phonetic feature which has been subjected to frequent and extensive investigations on the part of many researchers (e.g. Raphael,1972; Mckay,1980; Maddieson,1985 among others). Duration is defined as "the length of time involved in the articulation of a sound or a syllable" (Crystal,1997:127-128). Roach (2002:23) maintains that duration is a significant feature. He states that "the amount of time a sound lasts for is a very important feature of that sound."

Impressionistically, speech sounds are perceived either as long or short sounds depending on their length contrasts whose role is considered as an important linguistic cue for distinguishing one word from another. For example, the English words /sIt/ 'sit' and /si:t/ 'seat', which contain the short vowel /I/ and the long vowel /i:/, respectively, denote distinct meanings (Malmberg,1963:75). That is to say, the length of a sound refers to the way listeners perceive a certain sound as longer or shorter than others. Additionally, a sound duration can be acoustically measured by manner of 'oscillograms and spectrograms' (Gimson,1980:88). Roach (op.cit.:23) remarks that "it is usual to use the term 'length' for the listener's impression of how long a sound lasts for, and 'duration' for the physical objectively measurable time." For instance, listening to the following syllables: /bIt/ 'bit', /bet/ 'bet', /bi:t/ 'beat', /bɔ:t/ 'bought' leads to perceive the first two words as containing short vowels, whereas the others as containing long vowels (Roach,ibid).

The juxtaposition of vowels and consonants in longer structures, namely syllables may affect the durations of each other under certain circumstances. In fact, vowel and consonant durations are so correlated that changing the duration of any segment may cause a variation of the duration of the other. To be more specific, segments tend to lengthen or shorten; yet, they maintain the syllabic duration relatively constant via some compensatory effort (Abercrombie, 1967:81).

The present chapter is devoted to give a detailed review of the previous studies that have tackled segmental duration and the factors via which it is affected as well as the timing compensation process that takes place between the durations of the adjacent segments.

## 3.2 Review of Literature

A great deal of attention has been paid to the investigation of segmental duration (vowel and consonant durations) in different languages. Most of the studies were conducted to explore the striking interrelationship that dominates the durations of adjacent segments and the way they affect the syllable as well as word overall duration. To come closer to the point, they were devoted to inspect the way the segments compensate for the durational differences they undergo in order to maintain duration consistency (temporal compensation). However, the segmental duration is also affected by several factors such as voicing, context, stress,...,etc.

The following is a presentation of the past studies that have dealt with segmental duration and the timing compensation process in addition to the factors that affect both vowel and consonant durations in different languages as well as in the Arabic language. The studies are arranged chronologically. And due to their abundance<sup>1</sup>, special emphasis is placed on those that have been carried out and published recently.

<sup>1.</sup> For example, Stetson,1951; Jones,1956; Zimmerman and Sapon,1958; Picket and Decker,1960; Peterson and Lehiste,1960; House,1961; Fintoft,1961; Delattre,1962; Han,1965; Nooteboom and Slis,1972; and Klatt,1974.

#### 3.2.1 Studies on Segmental Duration in Languages Other than Arabic

Across languages, it is obvious that the durations of adjacent vowel and consonant sounds constituted the main focus of a number of researches for decades. The present section is devoted to consider some of these studies which have examined vowels and consonants in terms of duration. They are reviewed in a chronological order as far as possible.

#### **Raphael**

In a study on the role of vowel duration in the perception of the voicing feature of word-final consonants in English, Raphael (1972) examined the relation between the preceding vowel duration and the perception of the voicing characteristic of word-final plosives and fricatives, and the consonant clusters of the forms: plosive+plosive, plosive+fricative and fricative+plosive which are embedded within minimal pair words. These forms were read by 25 subjects (5 males and 20 females) (Raphael,ibid:1297). The findings indicated that the consonants which are preceded by long vowel durations were perceived as voiced consonants, while those which are preceded by short vowel durations were identified as voiceless consonants (Raphael,ibid). The findings were in complete agreement with Malecot's (1970) viewpoint, as it was referred to by Raphael (op.cit.), which stressed that the durations of vowels before final consonants is "both a powerful and sufficient acoustic cue" helps distinguish voiced from voiceless consonants (Raphael,ibid).

#### Fujisaki et al.

In Japanese, there are certain speech sounds which expose durational contrasts; particularly, vowels, nasals and some voiceless consonants. Actually, the Japanese phonological system comprises five short vowels as well as their long counterparts. Likewise, Japanese consonants, for example, single voiceless fricatives occurring in word-medial position, denote distinctive durations from those of their long cognates, viz. geminates, due to the duration of 'quasi-

stationary friction' (e.g. /isoku/² 'transplantation' versus /issoku/ 'one colour') (Fujisaki et al.,1975:198-199). Regarding voiceless plosives, the durational contrast is represented by "a difference in duration of the stop gap preceding the plosion" (Fujisaki et al.,ibid:199). For instance, /supai/ 'spy' versus /suppai/ 'sour' and /ici/ 'one' versus /icci/ 'agreement'. Finally, the nasal consonants occurring in medial position exhibit the phonemic contrast by increasing the duration of 'the nasal murmur' (e.g. /ama/ 'nun' versus /amma/ 'message') (Fujisaki et al.,ibid).

Experimentally, Fujisaki et al. (ibid) inspected the role of segmental duration as a perceptual cue of Japanese vowels and consonants in various phonetic environments. Moreover, they examined the durational interactions between vowels and consonants, and the perception of different non-speech sounds which have similar features of natural speech sounds. The subjects on whom the experiment was carried out included normal-hearing and hearing-impaired children. The results indicated that the duration of long vowels or doubled consonants were more than twice the lengths of their shorter (single) partners. The results also disclosed that hearing-impaired children showed insignificant difference from the normal-hearing children in terms of their perceptual ability of the duration of non-speech stimulus items (Fujisaki et al., ibid:217).

#### **McKay**

McKay (1980) investigated word-medial plosive geminates in a north Australian language, namely Rembarrnga, to prove the validity of interpreting medial plosive contrasts on the basis of occurrence as a single or geminate sound regardless of the voicing characteristic of the plosive consonant. In Rembarrnga, the voiced and voiceless plosives are partly in complementary distribution exposing contrasts only in word-medial position, except in word-medial position after nasals. The interpretation of gemination of medial plosives contrasts were

<sup>2.</sup> The transcriptions of the stimulus items are retained in this review in accordance with their original sources.

supported by the morphophonemic analysis of the language in question. McKay (ibid:344) reported that there was a" fairly strong evidence from the use of various affixes in support of the gemination interpretation. Where affixes and stem bring together two identical stops the result is a long, voiceless, fortis stop. If only one (syllable initial) stop occurs, it is short, voiced and lenis." The findings demonstrated that the 'occlusion' duration of a geminate plosive was significantly longer than the occlusion duration of its single counterpart.

However, the shortening of vowels preceding a geminate plosive appeared to be negligible. Finally, it was concluded that "structural and spectrographic evidence appears to indicate that the opposition between medial stop in Rembarrnga – short lenis versus long fortis – can and should be interpreted as an opposition between single and geminate stops" (McKay,ibid:346).

#### Maddieson

In as far as segmental duration is concerned, Maddieson (1985) suggested what was called 'closed syllable vowel shortening rule' which he examined. According to Maddieson (ibid), the closed syllable vowel shortening rule implies that intervocalic geminate consonants which occur in 'word-internal' position negatively affect the duration of the preceding vowel. That is to say, the duration of the vowel occurring before a geminate consonant is shorter than that of the vowel occurring before its single counterpart.

For the purpose of inspecting the closed syllable vowel shortening rule, an experiment was performed. The data was selected from seventeen languages of different language families. It was found that the preceding vowel duration tended to lengthen before a non-geminate consonant, whereas it tended to shorten before its geminate cognate within the phonetic contexts examined.

However, one of these languages, namely Japanese showed the opposite tendency, i.e. vowel duration in Japanese was not affected by the following consonant duration whether it is a single or geminate consonant (Maddieson,ibid).

#### **Braunschweiler**

In an experimental inspection of the effects of phonological representations on the temporal relations in the production of word-medial /-VC-/-sequences, Braunschweiler (1997) examined vowel duration, closure duration and release duration in a set of disyllabic words in German. The words under inspection yielded length contrasts, i.e. they contained the vowels /a/ versus /a:/ followed by the plosives /p,b/, /t,d/ and /k,g/. In fact, Braunschweiler (ibid) intended to detect the degree to which the duration of the vowel and the following plosive closure duration interacted to discriminate medial consonants. The results made it evident that both long and short vowels showed an obvious tendency to lengthen before voiced plosives than before their voiceless counterparts. Additionally, the findings indicated that the closure durations of voiced plosives were shorter than those of the voiceless ones even though such a case could not be attributed to the lengthening of the preceding vowel (Braunschweiler,ibid).

#### Gordon et al.

Gordon et al. (1997) conducted an experimental investigation of several phonetic features of a Muskogean language spoken in Oklahoma, namely Chickasaw. That is to say, they inspected vowel quality, vowel duration, VOT and consonant closure duration (Gordon et al.,ibid:1). Actually, Chickasaw vowel system includes three different vowel qualities, i.e. short, long and nasalized vowels. Yet, the nasalized vowels function phonetically and phonologically the same way as long vowels, viz. rhythmically lengthened vowels. Chickasaw phonological system contains a further set of vowels. In this connection, Gordon et al. (ibid:2) mentioned that this set of vowels

... plays a pervasive role in the phonology arises from a progress of phonetic lengthening in alternate open syllables. This process of rhythmic lengthening lengthens the second in a series of two consecutive phonemically short vowels in open syllables that are not word final.

A wordlist of 150 words which showed up the basic phonetic characteristics of Chickasaw was prepared. The words were recorded over two stages. In the first stage the wordlist was read by one female subject. In the second stage, it was uttered by 13 subjects (6 males and 7 females), that every subject repeated each word twice (Gordon et al.,ibid).

The durations of short, long and lengthened vowels were measured. Based on the measurements, it was found that long vowels had the longest duration, whereas the short vowels had the shortest duration, and that the durations of lengthened vowels were midway between long and short vowels. It was also found out that the durational difference between long and rhythmically lengthened vowels was smaller than that between rhythmically lengthened and short vowels (Gordon et al.,ibid:10). More to the point, Gordon et al. (ibid:19) inspected the durational correlation between single and geminate consonants; therefore, they measured the closure durations for a number of non-geminate versus geminate pairs in similar phonetic contexts. Considering the results, it was noticed that there was small difference between single and geminate consonants durations and that the duration ratio between single and geminate consonants was 'much smaller' than 2:1. The little durational ratio between the non-geminate consonant and its geminate counterpart might be attributed to the syllabic structure of the word (Gordon et al., ibid). Additionally, the findings strikingly showed that vowels occurring before non-geminate consonants were significantly longer than those occurring before geminate consonants; particularly, before the single versus geminate bilabial plosives (Gordon et al.,ibid).

More to the point, Gordon et al. (ibid:23) reported that the closure duration ratio of a single versus geminate consonant in Chickasaw was smaller than that in many other languages. For instance, in Standard Finnish, Estonian and Bengali the geminate was twice the length of its non-geminate partner. Yet, in Japanese, Italian and Arabic, geminates were more than twice the length of their single cognates. On the other hand, in Turkish and Hungarian, geminates were three times the length of their single partners. Notwithstanding, there are other languages which exhibit

small difference ratio between single and geminate consonants as in Dorgi and Icelandic.

#### Giovanardi and Di Benedetto

In Italian, Giovanardi and Di Benedetto (1998) experimentally inspected the phenomenon of gemination; specifically, they examined single versus geminate fricatives. A wordlist containing several minimal pair disyllabic words containing the structures /VCV/ versus /VCCV/ was prepared, and read by six native speakers of Italian. The fricative consonants examined within these words comprised /f, v, s/ surrounded by one of the vowels /a, i, u/. All of the words had stress on the first syllable (Giovanardi and Di Benedetto,ibid:4). See table (3.1) for more clarification.

**/f/** /ff/ **/v/** /vv/ /SS/ /SS/ /a/ /afa/ /affa/ /ava/ /avva/ /asa/ /assa/ /ifi/ /iffi/ /ivi/ /ivvi/ /isi/ /i/ /issi/ /ufu/ /uvu/ /usu/ /uffu/ /uvvu/ /ussu/

**Table (3.1): The Complete Set of Structures** 

After Giovanardi and Di Benedetto (1998).

The results showed that the geminate fricatives were longer than their non-geminate partners; therefore, a geminate fricative negatively affected vowel duration, i.e. it shortened the durations of the preceding and the following vowels. It was contended that there was a significant correlation between segments in terms of duration (Giovanardi and Di Benedetto,ibid). They also stated that "an increase in the duration of the consonant leads to a shortening of the two vowels V1 and V2, and vice versa, which means that this effect is present also in absence of gemination" (Giovanardi and Di Benedetto,ibid:12). That is to say, both the preceding and the following vowels tended to lengthen before and after a single fricative rather than before and after its geminate partner.

#### Scobbie et al.

Scobbie et al. (1999) studied duration in Scottish Standard English spoken in Glasgow. The Scottish vowel system comprises 12 vowels: "six bimoraic monophthongs /I, e, a, D, O, H/; three monomoraic monophthongs /I, E, N/; three bimoraic diphthongs /ai, aH, Di/" (Scobbie et al.,ibid:1617). Yet, the Scottish vowel length rule basically applies to three vowels: the high bimoraic vowels /i/ and /H/ and the diphthong /ai/. To come closer to the point, Scobbei et al. (ibid.) mentioned that Scottish Standard English has certain secondary phonetic features which are basically conditioned by two factors. First, the voicing feature of the following consonant; second the occurrence of a post-vocalic morpheme boundary. In other words, the Scottish vowel length rule implies that some Scottish vowels "are long in open syllables and before voiced fricatives, /r/ and a morpheme boundary, and short elsewhere" (Hewlett et al., 1999:2157).

Scobbie et al. (op.cit.1618) conducted an experimental work where they detected vowels affected by the Scottish vowel length rule. Thus, a wordlist was prepared including 'near' minimal pair words which contained the vowels /i, te, a, o, ɔ/ before the consonants /-t, -d, -s, -z/. The words were spoken by 32 speakers (16 males and 16 females) at their natural speech rate. Each word was spoken only once. The findings confirmed that the vowels /i/ and /te/ hardly lengthened before a voiced plosive; yet, they largely lengthened before a voiced fricative. In the event of /a/-sound, it was noticed that the variation of its duration brought about a change of quality. Finally, it was deduced that the Scottish vowel length rule affected only /i/ and /te/, while other vowels behaved more like those of English (Scobbie et al.,ibid:1619).

#### **Mattie and Di Benedetto**

In Italian, Mattie and Di Benedetto (2000:1) investigated the differences

between non-geminate and geminate nasals in relation to several parameters: time, frequency, and energy. Experimentally, the data comprised words containing the structures /VCV/ vs. /VCCV/ in which the three Italian vowels /i, a, u/ represented the vowel element and the nasals /m/ vs. /mm/ and /n/ vs. /nn/ represented the consonant element. See table (3.2) for illustration.

**Table (3.2): The Complete Set of Structures** 

	/m/	/mm/	/ <b>n</b> /	/nn/
/a/	/ama/	/amma/	/ana/	/anna/
/ <b>i</b> /	/ <b>imi</b> /	/immi/	/ini/	/inni/
/ <b>u</b> /	/umu/	/ummu/	/unu/	/unnu/

After Mattie and Di Benedetto (2000).

The findings signified that geminate nasals were longer than their single counterparts. A difference which resulted in shortening the vowel duration occurring before a geminate rather than before a single nasal (Mattie and Di Benedetto,ibid:11).

#### Faluschi and Di Benedetto

The difference between single and geminate affricates, in Italian, was also inspected by Faluschi and Di Benedetto (2001). For this purpose, they prepared a wordlist containing a number of disyllabic minimal pair words containing the structures /VCV/ versus /VCCV/ where the vowels /i, a, u/ and the Affricates /tʃ, dʒ, ts, dz/ were employed. The words were spoken by 6 Italian native speakers (3 men and 3 women) and each word was pronounced three times (Faluschi and Di Benedetto,ibid:2). The results confirmed that geminate affricates were characterized by longer durations than their single partners. As a result, a geminate affricate negatively affected the preceding vowel, i.e. it shortened the duration of the preceding vowel. This definitely signified a compensatory

shortening process on the part of the preceding vowel duration when occurring before geminate affricates rather than before their single partners. In this connection, Faluschi and Di Benedetto (ibid:4) contended that "this observation leads to suppose that a compensation effect (even if incomplete) takes place between V1,C1 durations. This compensation effect is the element that tends to make the phonetic rhythm almost unchanged."

#### Hansen

Hansen (2004) studied the production of geminates in Persian at three distinct speaking rates; besides, he measured consonant and preceding vowel durations as well as the word overall duration. The study was basically intended to inspect whether a geminate consonant duration was reduced to the extent that it becomes within the range of a single consonant duration when spoken at fast speech rate, and whether the duration of the preceding vowel and the speaking rate may help distinguish a single from a geminate consonant. A wordlist containing 12 disyllabic words which display single/geminate contrasts was prepared. More specifically, they contained the non-geminate versus geminate alveolar plosives/t,d/ occurring in intervocalic position with stress to be placed on the second syllable (Hansen,ibid:87).

The results indicated that the decrease in the geminate durations was much more dramatic than the decrease in the non-geminate durations even though the single consonant also decreased consistently with speech rate. It was also found that the duration of the preceding vowel also decreased as the speech rate was increased (Hansen,ibid:89). Different from most languages, the vowels, in the Persian language, tended to lengthen before long consonants (geminates) rather than before single ones (Hansen,ibid).

# 3.2.2 Studies on Segmental Duration in Arabic

In Arabic, just like in other languages, the reciprocal relationship between the durations of adjacent vowels and consonants was investigated by a number of researchers who acoustically studied the segmental duration of both vowels and consonants. Below is a review of the most prominent studies that have dealt with segmental duration in Arabic.

#### **Obrecht**

Obrecht (1965) experimentally investigated the phonetic duration of Arabic consonants. He tested the possibility of using phonetic duration as a perceptual cue to the nature of the consonant, i.e. whether it was single or geminate. Three consonants showing single versus geminate contrasts were selected, viz. /b/ versus /bb/, /n/ versus /nn/ and /s/ versus /ss/. The plosive and nasal consonants were examined in inter-vocalic position (/xabar/ 'news' versus /xabbar/ 'he informed' and /bana/ 'he built' versus /banna/ 'mason'), whereas the fricative consonant was tested in the initial position (/sabij/ 'a boy' versus /ssabij/ 'the boy'). The minimal pair words were spoken by a number of subjects in three separate tests. The first test included the minimal pair /yabar/ versus /yabbar/ produced by five speakers.

The measurements showed that closure durations of 140 ms. and 160 ms. were perceived as /b/ versus /bb/, respectively. The second test contained /bana/ versus /banna/ which were recorded by 15 subjects. The results demonstrated that the durations of 90 ms. and 110 ms. were perceived as /n/ and /nn/, respectively. The third test comprised the minimal pair /sabij/ versus /ssabij/ which were read by three subjects in order to "investigate the perceptual boundary between single and geminate consonants" (Obrecht,ibid:37). The results denoted that the /s/ was identified as a single consonant at 80 ms.; while the duration of 200 ms. represented a geminate consonant. It was obvious that the subjects perceived short durations as single consonants, whereas long durations were identified as geminate consonants.

#### **Hassan**

Hassan (1981) conducted an experimental study on vowel duration in Iraqi

spoken Arabic. He tested the durations of vowels preceding non-geminate versus geminate consonants. The results were compatible with those which were later reported by Ghalib (1984) in as far as the durations of single versus geminate consonants were concerned. That is to say, geminate consonants were found to be significantly longer than their single cognates. Moreover, Hassan (ibid) discovered that vowels tended to be 'essentially' longer before single consonants than before their geminate counterparts. Though the vowel durational difference before a single versus geminate consonant was small, it was significant.

Furthermore, Hassan (op.cit.) examined the articulatory and aerodynamic differences between a voiceless geminate plosive and its single opposite. The results indicated that geminate consonants were articulated with oral pressure greater than that required for the articulation of single ones. In addition, it was found out that a geminate plosive was characterized by longer closure duration than that of its non-geminate partner; besides, its articulation was accompanied by higher oral pressure, despite its occurrence, in some cases, in stressed positions.

In a recent attempt, Hassan (2002) has carried out an acoustic comparative study to investigate gemination and its effect on preceding vowel duration in Arabic and Swedish. It is well known that the Arabic vowel system comprises three short vowels as well as their long counterparts. On the other hand, the Swedish vowel system consists of nine vowels besides their long cognates. In Arabic, vowel length is deemed to be phonemic, i.e. it helps differentiate the meaning of one word from that of another. Similarly, geminate consonant length in Arabic is also contrastive, e.g. /'Sadad/ 'number' versus /'Saddad/ 'he enumerated'. Conversely, in Swedish, vowel length is considered to be allophonic, and that "a phonologically long stressed vowel is followed by a short consonant and a phonologically short vowel is followed by a long consonant (geminate or consonant cluster)" (Hassan, ibid:81).

Two wordlists including disyllabic words spoken by native speakers of both Arabic and Swedish were prepared. The words were uttered in isolation and within a carrier sentence. The durations of the segments under investigation were measured (Hassan,ibid:82). The results disclosed that the durations of geminate consonants were significantly longer than those of their non-geminate partners for both languages. Regarding the preceding vowel duration, it was found that, in Arabic, vowels before single consonants were 'slightly' longer than those before geminate consonants. Differently, it was observed that vowel duration, in Swedish, was significantly longer before single rather than before geminate consonants. Thus, the consonant and vowel durations can be considered as language-specific to the extent that they function as a perceptual cue for Swedish listeners. The findings also indicated that, in Arabic, consonant length is contrastive though the shortening of the preceding vowel was looked at as 'language universal phenomenon' that might be attributed to "the articulatory nature of gemination and the resulting myodynamic and aerodynamic conditions" (Hassan,ibid:82).

#### **Ghalib**

In an extensive phonetic study, Ghalib (op.cit.) experimentally investigated the phenomenon of gemination in one of the Arabic dialects spoken in Iraq, viz. the Iraqi Colloquial Arabic dialect (I.C. Arabic for short). Specifically, the research was intended to investigate the durational differences between non-geminate and geminate consonants when occurring in word-initial and word-medial positions, and to determine whether such distinctions could be considered phonemic (Ghalib,ibid:152). For this purpose, two opposite sets of words containing /s/versus /ss/ and /d/ versus /dd/occurring in word-initial and in word-medial positions were arranged. Thus, the selected stimulus items included words such as: /sabit/ 'Saturday' versus /ssabit/ 'the Saturday', /hasan/ 'a proper noun for males' versus /hassan/ 'he improved', /darub/ 'road' versus /ddarub/ 'the road', /badal/ 'substitute' versus /baddal/ 'he altered'. All of the words have primary stress on their first syllables. The words were all read in isolation and within a carrier sentence by the researcher himself (Ghalib,ibid:151-152).

The acoustic measurements extracted from spectrograms showed that the geminate fricative /ss/ was very significantly longer than its single counterpart

when produced both in isolation and within context (Ghalib,ibid:168). In addition the durational differences were also demonstrated in the event of /d/ and /dd/ when occurring in word-initial and word-medial positions. It was recognized that the duration of /dd/ was considerably longer than twice the length of its single cognate /d/; particularly, when occurring in word-medial position. In as far as vowels were concerned, it was found that the vowel /i/ in the words /sabit/ and /ssabit/ revealed negligible durational differences. The vowel /a/ in the first syllables of the words /hasan/ and /hassan/ varied its duration insignificantly. By the same token, the vowel /a/ in the second syllables of the same words exposed insignificant durational variations. Besides, /a/-sound was slightly longer in /darub/ than that in /ddarub/ (Ghalib,ibid:172-173).

The findings made it clear that geminate consonants, regardless of their manner of articulation, had longer durations than their single partners. On the other hand, the results demonstrated that "in I. C. Arabic vowels occurring in stressed positions seem to maintain their original length whether they precede or follow a geminate consonant, and whether they exist in words spoken in isolation or in words pronounced in a contextual utterance" (Ghalib,ibid:178).

# 3.3 The Nature of a Geminate Consonant

There have been long debates among phoneticians and phonologists (e.g. Malmberg,1963; Jones,1967; Abercrombie,1967; Ladefoged,1975; and Catford,1988 among others) about the nature of the geminate consonant, i.e. whether to consider it as a single long consonant or a doubled consonant consisting of two divisible sounds.

In fact, there is a difficulty to identify the difference between long and doubled consonants. For instance, Malmberg (op.cit.:77) refers that consonants can show length contrasts, i.e. they can be either short or long. He contends that the adjectives 'long' 'double' and 'geminate' can be used synonymously. As for his part, Jones (op.cit.:116-117) claims that it practically appears too appropriate to

regard long consonants as doubled ones due to the possibility of dividing them into two parts by "diminution of force in the middle, attaching the first part to the first syllable and the second part to the second syllable." Many examples can be recognized in English at syllabic boundaries, and words containing prefixes or suffixes as well as compound words, as in 'book-case' and 'genuineness'. In the case of initial long consonants, it seems to be appropriate to consider them as double. As a result, the first part is regarded either as "a prefix or as an element", as in Luganda, /tta/ 'kill' and /ggwa/ 'be finished'. Likewise, long consonants which occur in final positions are considered as double in all cases; specifically when the second element is syllabic, as in /dakk/ 'sandhill' and /latt/ 'to be sweet' (Jones,ibid:117).

Nevertheless, in some languages, like English and Swedish, double consonants are regarded as long consonants that the preceding vowel and final consonant durations are so correlated, whereas in languages like Hungarian and Estonian, there is no such correlation. In English, for example, /l/ in 'hill' is a long consonant for it is preceded by the short vowel /I/; therefore, /l/ is not considered as double. Similarly, in Swedish, some medial and final consonants are considered as long rather than double, although they are orthographically represented as doubled consonants, for example, /l/ in /vIlljæ/ 'choose' (Jones,ibid). Thus, Jones (ibid:120) affirms that "the terms long and length are used only in reference to sounds having true or indivisible length."

Abercrombie (op.cit.) stresses that it is necessary to differentiate between double and long consonants. He states that "a double consonant is one whose duration extends over two syllables, whereas the duration of a long consonant is confined to a single syllable" (Abercrombie,ibid:82). Consequently, in languages, like English, double consonants are positioned at syllabic boundaries, as in 'wholly' and 'this study'. Ladefoged (op.cit.) remarks that consonants of long durations, which are interpreted as double, are known as 'geminates'. The term geminate is derived from the Latin word 'geminare' which means 'to double'.

A geminate can be defined as "a sequence of two identical, or nearly identical consonantal sounds" (Catford,op.cit.:111). Catford (ibid:111-112) considers sequences, such as /-ss-/, /-kk-/, and /-nn-/, from a phonetic point of view, examples of geminates. Yet, the term geminate refers to identical consonant sequences which occur within the same syllable or morpheme, such cases are known as 'true geminates', as in Italian notte 'night', and in Arabic Allah 'God'.

Kenstowicz and Pyle (1973) have studied geminate sequences in an American language of California, viz. Sierra Miwok. They define a geminate as "a sequence of identical consonants or vowels" (Kenstowicz and Pyle,ibid:27). The material selected involves alternations between the present and past tense structures of three types of verbs. It is observed that long consonants are represented by a sequence of identical segments instead of a single segment marked plus long. As a result, two rules are proposed. The first rule implies that vowels shorten before consonant clusters and long consonants, while the second rule treats long consonants like clusters in stress rule. Thus, it is deduced that long consonants should be considered as geminates because it is believed that long consonants behave in a way similar to that of consonant clusters (Kenstowicz and Pyle,ibid:28).

Regarding the Arabic language, all consonants can be geminated in word-medial position where they become longer in duration than single consonants. However, in Arabic, geminate consonants are not represented orthographically by two letters. Instead, a sign ( ) known as /ʃadda/ is used to characterize the geminate consonants and distinguish them from their single counterparts (Ghalib,op.cit.:27). It is also reported that, in Arabic grammar, geminate consonants are considered to be long consonants. Nevertheless, it is preferred to deal with a geminate consonant as a double consonant consisting of a sequence of two identical sounds without an intervening vowel. For example, /ˈkasar/ 'he broke' versus /ˈkassar/ 'he smashed' (Ghalib,ibid:28).

Mitchell (1993), as referred to by Kiparsky (1999:19), phonetically describes geminate consonants in Arabic. He contends that initial and medial geminates share the same phonetic characteristics of length and tenseness. In this connection, Mitchell (op.cit.:92) explains that:

All types of gemination reveal not only an increase of duration over non-gemination but also greater muscular tension and pulmonary pressure, a more extensive spread of tongue-palate contact, increased loudness of adjoining vowels and incisiveness of on- and off-glides (especially in the case of plosive consonants), as relevant phonetic characteristics.

As for Selouani and Caelen (2004), gemination stems from "the intensification of the articulation and the sustained (prolongation) plosive closure." Phonologically, they look at such a phenomenon, viz. gemination, as "the doubling of the consonant" (Selouani and Caelen, ibid: 2).

# 3.4 Factors Affecting Segmental Duration

It is indicated, on the part of many phoneticians and phonologists (e.g. Heffner, 1950; Zimmerman and Sapon, 1958; House, 1961; Jones, 1967; and Klatt, 1976 among others), that segmental duration may be influenced by several factors. However, these factors cannot be separated from each other. Instead, they corporate. Klatt (ibid), as mentioned by Port (2000:11), contends that although vowel duration may be influenced by various factors, it seems that the effects of each factor partly depend on how the other factors function at the same time. For example, the vowel /æ/ in /ræpɪd/ 'rapid' is shorter than that in /ræbɪd/ 'rabid' This can be ascribed to the voicing feature of /b/-sound. This is also true of /læp/ 'lap' versus / læb/ 'lab'. In addition, the vowel /æ/, in the former minimal pair

words is shorter than that in the latter due to the existence of another syllable in /ræpɪd/ versus /ræbɪd/. Moreover, van Son and van Santen (1997:1) maintain that the factors affecting segmental duration strongly interact to the extent that it is difficult to set them apart. The following sections shed light on some of these factors that affect both vowel and consonant durations.

# 3.4.1 Speech Tempo

Tempo is defined by Crystal (op.cit.:384) as the "speed of speaking; alternatively known as rate." Each speaker may enunciate various utterances at different tempos in accordance with the situation in which he/she is involved. For instance, the speaker may slow or fasten the speed at which he/she speaks. Abercrombie (op.cit.:96) contends that every speaker speaks at his own characteristic tempo which distinguishes him from other speakers. Recently, a great deal of attention has been paid to the study of how tempo influences the pronunciation of different words when spoken at slow or fast speech rate and how the process of varying tempo linguistically functions as a conveyer of information; therefore, "this linguistic use of rate is frequently called tempo" which is either by syllables per second or phonemes per second measured (Roach,op.cit.:79). Heffner (op.cit.:204) explicates that there is a reciprocal relationship between tempo and duration. More specifically, changing the speed of speaking can vary both vowel and consonant durations. That is to say, the faster is the tempo, the shorter is segment duration and vice versa (Malmberg,op.cit.:74-75). Additionally, speakers of any language may speak quickly or slowly that these different tempos can be employed to accomplish expressive purposes. For instance, when the utterance 'He was a big, strong bear of man' is spoken at a slow tempo, i.e. the syllables of the utterance in question are lengthened, this results in "a stronger impression of this bear-like character" than when it is said at normal tempo (O'Connor, 1973:198).

In an experimental study of prosodic effects on segmental duration, e.g.

syllable structure, stress and tempo in four languages, namely American English, British English, Greek and Swedish, Botinis et al. (2002:77-8) inspect the effect of tempo by examining disyllabic nonsense words of the structure /CVCV/ where the voiceless fricative /s/ stands for the (C) element and the vowel /a/ represents the (V) element. The words are uttered within a carrier sentence by four speakers of each language. The data is spoken at two tempos, viz. normal and fast, and with alternative stress patterns, i.e. stress is either placed on the first or the second syllable.

The results display that tempo has a considerable influence on the durations of vowels and consonants. In as far as vowel duration is concerned, the findings reveal significant variations in the languages investigated. In regard to consonant duration, it is found that consonant duration is significantly affected by tempo variations in these four languages (Botinis et al.,ibid:78). It is clear that tempo has the most 'substantial' effect on both vowel and consonant durations in the languages examined (Botinis et al.,ibid:80).

According to Byrd and Tan (1996:263), "faster speech rates cause a succession of the phonological units to occupy less total time." For this purpose, they conduct an acoustic experiment to examine several temporal aspects that are affected by changing speech rate; particularly, consonant duration. More specifically, they investigate whether individual consonants in /C#C/ sequences tend to shorten as a reaction to the increased speech rate. The EPG is used and recordings of five monolingual English speakers (2 men and 3 women) are made (Byrd and Tan,ibid:266-268). The results show that consonants at word boundaries, generally, tend to shorten when speech rate is increased regardless of the place and manner of articulation of these consonants (Byrd and Tan,ibid:276).

Ghalib (op.cit.), in his study on gemination in I.C. Arabic, finds that single and geminate consonants pronounced in words produced with slow tempo are significantly longer than those enunciated in words spoken with fast tempo even though the durational differences between single and geminate consonants are still

prominent whether they are used in words spoken with slow or fast tempo. More to the point, long segmental durations undergo 'major reduction' more than short segments. In this respect, Ghalib (ibid:532) contends that "the longer the sound segment is the greater reduction in its duration it suffers when it is produced at rapid rates of speech. Since geminate consonants are longer than single consonants, they are liable to be more severely shortened at fast speech rates than their single partners." Vowels are also negatively affected when tempo is increased. However, they undergo relatively little reduction of their durations as they are pronounced in words said with fast tempo as compared to consonants. This finding coincides with Hansen's (op.cit.) results, (§3.2.1), in as far as the effect of speaking rate on both vowel and consonant durations are concerned.

# 3.4.2 Syllable Structure and Stress Patterns

It has been proved that duration of segments are affected by the structure of the syllable where they cluster. In this respect, Abercrombie (op.cit.) explains that, in English, all monosyllabic words tend to be of the same length under similar conditions. Yet, there is 'considerable' differences on the part of the lengths of the individual sounds of which the monosyllabic word is constituted. As a result, initial consonants tend to be 'uniformly' very short. Regarding the lengths of the remaining sounds within the monosyllabic word, they depend, according to Abercrombie (ibid:81), on two factors. The first factor "is the pattern of structure" in which they find themselves. Thus the vowel in a syllable of the pattern CV0 is longer than the vowel in a CVC pattern, which is in turn longer than in a CVCC pattern." This is definitely clear in the syllables /bi:/ 'be', /bi:t/ 'beat' and /bi:st/ 'beast'. The second factor "is the phonetic nature of the segments themselves." Consequently, a final voiced consonant tends to be shorter than a final voiceless one, and therefore the preceding vowel tends to lengthen before a voiced consonant rather than before a voiceless one. For example, the monosyllabic words /bi:t/ 'beat' and/bi:d/ 'bead' have the same length, however, the duration of vowel /i:/ in the former is shorter than that in the latter.

According to Jones (op.cit.:124), duration can be affected by certain 'chief' factors. One of these is the syllabic structure as well as 'degree of stress'. He contends that segmental duration is influenced by the number of syllables that intervene "between one strong stress and the next." In stress-timed languages where strong stress occurs at equal intervals (rhythm), the durations of segments are often constrained. In other words, when strongly stressed syllables are followed by weakly stressed syllables over equal points in time, some segments unintentionally tend to shorten in order to "make the stress bar equal in length to other stress bars" (Jones,ibid:124). For instance, the English long vowel /ɔ: / is longer when it is pronounced in an isolated word than in the clause /ðə 'kɔ:z əv It wəz 'nevə dɪs'kʌvəd/ (Jones,ibid:125-126).

Botinis et al. (op.cit.:78) also emphasize the significant effect of syllable position on segmental duration. For instance, it has important influence on consonant duration in British English and Greek, whereas in American English and Swedish it shows negligible effect. As for vowel duration, it is found that syllable structure significantly affects vowel duration in British English and Greek. Yet, vowel duration exhibits insignificant variation in American English and Swedish. Botinis et al. (ibid:80) remarks that "syllable position may have a lengthening effect on segment durations, according to which final segments at variable linguistic units (e.g. word, phrase, utterance) may be longer than non-final counterparts."

van Son and van Santen (op.cit.:1-2) have carried out an experimental research to inspect the interaction between factors which affect consonant duration, such as stress and consonant position within a word. Two subjects (a male and a female) have participated in the experiment. They have been asked to read aloud a group of sentences. The sentences contain all the possible /VCV/ 'realizations' of the consonants /t, d, k, g, f, v,  $\delta$ ,  $\theta$ , s, z,  $\int$ , d $\delta$ , m, n,  $\eta$ , l, r, j/. They have examined consonants durations in three positions, i.e. word-initial, word-medial and word-final positions. The results show that consonants occurring in initial and medial

positions within stressed syllables have similar durations and are both longer than word-final consonants occurring in stressed syllables. In addition, consonants occurring in word-medial and word-final positions clustering within unstressed syllables have 'similar' durations which are, in turn, different from those of consonants located in word-initial position clustering within unstressed syllables. More to the point, they have found that there is no difference between the durations of the consonants occurring in final positions within stressed and unstressed syllables, whereas the difference between them is clear when they occur in initial and medial positions (van Son and van Santen, ibid:5).

# 3.4.3 Phonetic Context

It is well known that speech sounds influence the durations of one another when clustering within speech sequences. Malmberg (op.cit.:56) reports that "consonants are united with vowels to form syllables. Syllables form groups, phrases, sentences. While grouping in this way, sounds influence one another and are modified in various ways." Jones (op.cit.) argues that segmental duration is affected by the nature of the adjacent sounds, i.e. it is constrained by the phonetic context in which sounds occur. For example, the English long vowel /i:/ in /si:/ 'sea', /si:d/ 'seed', /si:n/ 'seen', /si:t/ 'seat', /si:tiŋ/ 'seating' lengthens in different degrees where its durations are 0.37, 0.252, 0.199, 0.124, and 0.087 sec., respectively. This can be attributed to the effect of the adjacent consonants on the length of vowel /i:/ in addition to the point that whether it is pronounced in words produced in isolation or within context. Abercrombie (op.cit.:81) expounds that segmental duration is affected by the phonetic nature of the neighbouring sounds. As a result, a vowel tends to shorten before a voiceless consonant, while it lengthens before a voiced consonant. For instance, /bi:d/ 'bead' and /bi:t/ 'beat' have the same duration; yet, the vowel /i:/ in the first is twice as long as in the second.

de Lacy (1998) has experimentally investigated the effect of word-final consonant clusters on vowel duration. He has measured the duration of the vowel

/I/ in 64 monosyllabic words of the form /tIC(C)(C) / where the initial/t/ is kept unchanged. The consonant clusters include the consonants /t, d, s, z, n, l, tf, dʒ/. The words are uttered by three speakers within a carrier sentence. The duration of vowel /I/ occurring before a single voiceless consonant is shorter than that occurring before a single voiced one. In the event of two consonant clusters, the vowel /I/ duration is examined. It is found that its duration before /tft/ cluster is 153 ms. and before /d\(\frac{1}{2}\)d\(\frac{1}{2}\) is 191 ms., whereas its durations before single /tf/ and /dʒ/ are 158 and 218 ms., respectively (de Lacy, ibid:). de Lacy (ibid:16) explains as to why the effect of consonant clusters on vowel duration tends to be small though it is 'systematic'. He assumes that "each syllable is assigned some specific duration. Addition of segments, then, causes shortening since there is less duration left for the vowel." Thus, sequences of voiceless plosives or fricatives cause shortening of the duration of the vowel. This definitely implies that vowel duration "should become increasingly shorter with longer and longer sequences of consonants" (de Lacy, ibid:16). With regard to the effect of phonetic context on segmental duration, Behne et al. (1998:1) have referred to the effect of vowel environment on consonant duration in Swedish. They have reported that vowel quantity affects postvocalic consonant duration, i.e. there is an inverse relationship between the vowel and the following consonant durations. Thus, a short vowel is followed by a relatively long consonant and vice versa (e.g. /k:/ in /tak:/ tach 'thanks' versus /k/ in /tå:k/ tak 'roof').

# 3.4.4 Manner of Articulation and Vowel Quality

Although it is considered by House (op.cit.) as a secondary factor, manner of articulation may, to some extent, affect vowel duration. House (ibid:1177) explicates that:

It is appealing; however, to speculate that some inherent articulatory influences on vowel duration do

exist in general. The articulatory processes that seem to qualify are the manner of production of consonant contexts and the open-close dimension of vowel articulation (other things being equal).

He also reports that vowels are 'slightly' shorter before plosives than before fricatives. Moreover, vowel duration is also associated with tongue height. It is contended that vowel duration is negatively correlated with tongue height. In an experimental investigation, Raphael (op.cit.:1299) has discovered that the duration of the preceding vowel is affected by the different types of manner of articulation. Specifically, the results signify that vowels before fricatives are 'consistently' longer than those before plosives. Therefore, the averages of the 'critical durations' of vowels which precede fricative consonants are considerably longer than those of vowels which precede plosives.

Recently, Chung et al. (2003:1) have examined some consonantal and prosodic influences on vowel duration in Korean; particularly, the effect of different obstruents on vowel duration. For this purpose, a set of 384 artificial words are spoken by a single speaker. Throughout the experiment, they have intended to study the effect of four durational factors on vowel duration, i.e. the pre-vocalic context, the post-vocalic context, clause-final lengthening and phrase-internal shortening. The following table shows the consonants that can be available at the onset and coda positions in Korean. See table (3.3).

Table (3.3): The Korean Consonants Occurring in Onset and Coda Positions

Possible Consonants in Onset Position		
$p', p^h, p, t', t, t^h, k', k, k^h, t$ , $t$ ,		
Possible Consonants in Coda Position		
p, t, k, n, l, m, ŋ		

The study has yielded the following findings:

- 1. The pre-vocalic obstruent influences: The tense aspirated plosives greatly shorten vowel duration, followed by lax plosives. Tense unaspirated plosives have very little effect on vowel duration. This is also true of the affricates and fricatives. The tense aspirated affricate /tc/ greatly shortens vowel duration, followed by the lax affricate /tc/ and the tense unaspirated affricate /tc/. In the event of fricatives, the tense unaspirated fricative /s'/ shows less shortening effect than the lax one.
- 2. The post-vocalic obstruent influences: In Korean, the consonants /p, t, k/ as well as /m, n, ŋ, l/ which occur at the coda position have insignificant effect upon vowel duration.
- 3. The sonorant sound influences: The findings indicate that the /ʃ/-sound has smaller shortening effect on the following vowel duration when occurring in phrase-initial and clause-final position, while /m/-sound has the greatest shortening effect (Chung et al.,ibid:2-3).

As for vowel quality, it has been affirmed that one of the secondary factors that affects vowel duration is related to the articulatory nature of the vowel itself; more specifically, to tongue height. It is reported that vowel duration increases as the tongue becomes higher in one case and as the tongue becomes lower in the other one. Nevertheless, Jones (op.cit.) emphasizes that duration is related to vowel quality. For example, the vowels /i:/ and /I/ differ in their duration as well as quality. Jones (ibid:166) contends that "the longer sound always has the closer quality in a given phonetic context."

Zafeiri (2002-2003), for his part, has performed an experimental study to investigate the effects of several factors on vowel duration including the effect of vowel quality on vowel length in three English accents, viz. Southern British

English, Scottish English and General American English. He explains that vowels are distinguished on the basis of their qualities, i.e. every vowel is "determined by the position of the tongue and the lips during the articulation of the vowel sound" (Zafeiri,ibid:16). The results display the parameters that constitute vowel quality, viz. height, backness and tense-lax contrasts. Regarding height, it is observed that low vowels are significantly longer than high and mid vowels. As to backness, the findings demonstrate that there is a substantial significant effect of the degree of backness on vowel duration in the accents under investigation. For instance, the back vowels tend to be longer than front vowels. The results also disclose that tenseness affects vowel duration. It is found that tense vowels are longer than lax vowels (Zafeiri,ibid).

#### **3.4.5** *Voicing*

A further important factor that significantly affects vowel duration is the voicing characteristic of the adjacent consonant. Most researchers (e.g. Zimmerman and Sapon, op.cit.; House, op.cit.; Malmberg, op.cit.; Chen, 1970; Raphael, opcit. and others) contend that vowel duration is so correlated with the voicing feature of the subsequent consonant. It is emphasized that vowels tend to be longer in duration before voiced consonants than before their voiceless counterparts. Belasco (1953) has stressed that there exists 'a cause and effect' correlation between the duration of the vowel and the voicing feature of the following consonant. This relation is exposed in terms of what is labelled as 'force of articulation' of consonants. He remarks that there is a negative relationship between vowel duration and the articulatory effort necessary to produce the vocalic consonant. Belasco (ibid:1016)finds out that:

The anticipation of a consonant requiring a strong force of articulation will tend to shorten the preceding vowel since more of the total energy needed to produce the syllable is concentrated in the consonant. The opposite is true of course when the consonant has a weak force of articulation.

Chen (1970) has experimentally inspected the influence of the voicing feature of the following consonant in four languages, namely English, French, Korean and Russian. A wordlist for each language is prepared and read by native speakers in a way that an identical accentual pattern of each member of the minimal pairs is mentioned in order to avoid variation of the duration of the preceding vowel caused by a 'suprasegmental feature'. The results display that variations of vowel duration due to the voicing feature of the following consonant is 'presumably a language-universal phenomenon', whereas the degree of voicing effect on vowel duration is 'language specific', i.e. it depends on the phonological system of the language as such. Generally speaking, it is recognized that vowels are significantly longer before voiced consonants than before their voiceless cognates in the four languages examined. The durational variations of vowels are inversely proportional to the closure duration of the post-vocalic consonant. Precisely, since closure durations of voiceless consonants are longer than those of their voiced counterparts, the duration of the preceding vowel before voiceless consonants is shorter than that before voiced ones (Chen, ibid).

In a further study, de Jong (2001:826) has examined the effect of consonant voicing on vowel duration. His experiment comprises a wordlist read by four speakers (2 males and 2 females). The data selected includes the following syllables: pee, eap, bee, eab which are referred to as p-onset, p-coda, b-onset, b-coda, respectively. The acoustic measurements exhibit that vowels before codas tend to be affected more than those after onsets. It is also noticed that onset voicing brings about less durational differences, while duration variation caused by codas voicing is much more significant. The results also signify that vowel duration before /p/ is shorter than that before /b/ by relatively 50 ms. It is clear that the voicing property of the following consonant significantly affects the duration of the preceding vowel (de Jong,ibid).

Morrison (2002) has reported that, in Arabic, native speakers insignificantly vary the durations of Arabic vowels before voiceless versus voiced consonants. In other words, Arabic reveals negligible relation between the preceding vowel

duration and the voicing characteristic of the following consonant due to "the existence of phonemic vowel duration contrasts" (Morrison, ibid:18). As a result, vowel duration cannot be used as a perceptual cue to identify the following consonant in terms of the voicing feature. In this connection, Morrison (ibid:18) commented that "if a language uses vowel duration differences to cue phonemic vowel duration, then it may not be possible for that language to also use vowel duration to cue consonant voicing."

## 3.5 The Phenomenon of Temporal Compensation

Phoneticians (e.g. Abercrombie, op. cit.; Jones, op. cit.; Gimson, op. cit. among others) have expounded that there exists a constant and predictable relationship between the durations of segments within any syllable. This implies that changing the duration of any segment under the influence of some factors brings about variation of the durations of the other ones within the unit where these segments occur. This can obviously be observed in the behaviour of vowels and consonants in as far as their durations are concerned (Abercrombie, op. cit.: 81). Therefore, a timing compensation process is performed to keep the consistency of the durations of the syllabic units, and consequently the durations of larger units, namely words. Port et al. (1980:236) have stated that "temporal compensation, manifested as inversely correlated mean durations of adjacent acoustic intervals, serves in some cases as a device for maintaining macrostructure invariance despite microstructural variation." Similarly, Scully (1975:127) has stressed the significance of such a mechanism (temporal compensation) in maintaining duration invariance. She has emphasized that "temporal compensation aims at keeping the syllable approximately constant in duration."

Temporal compensation, as a phonetic phenomenon, propounds a compromise in speech production. In other words, the compensatory relationships that dominate between the durations of segments (vowels and consonants) within a certain unit (syllable) are interpreted as "the results of compromise between preferred segment durations and preferred durations for the prosodic

constituents containing them" (Flemming;1997:1). Hence, timing compensation springs from the essential requirement of compensation on the part of the durations of individual segments as well as the structural units containing them (Flemming,ibid:10).

Flemming (ibid) has inspected temporal compensation in an English data which includes words of the form /tVC/. The (V) element is represented by the sounds  $/\infty$ , a:, aI, I/ and the (C) element is represented by consonants /p, b, t, d,/. The words are uttered within a carrier sentence by a single speaker of American English. The results reveal that long vowels are followed by shorter consonants, whereas short vowels are followed by longer consonants. Such a pattern of temporal compensation is clearly noticed in the variation of the short vowel /æ/ duration. However, it is found that vowels do not vary their durations in accordance with that of the following consonant in a similar degree. For instance, the short vowel /æ/ exposes a considerably clearer pattern of timing compensation than that of the vowel /I/ which displays insignificant duration variation in relation to the post-vocalic consonant duration (Flemming, ibid). The findings confirm that vowels are shorter before bilabial plosives than before 'coronal plosives' and bilabial plosives are longer than 'coronal plosives'. And vowels occurring before voiceless plosives are shorter than those occurring before voiced plosives; besides, voiceless plosives are longer than voiced plosives. Generally, short vowels are followed by long consonants, whereas long vowels are followed by short consonants (Flemming, ibid: 11).

It is reported that there are similar compensatory patterns in languages other than English. For example, in Swedish, Icelandic and Norwegian, vowel and consonant durations compensate for each other, i.e. short vowels are followed by long consonants or consonant clusters, while long vowels tend to lengthen when they occur in open syllables and when they are followed by short consonants (Flemming,ibid.). Flemming (ibid:10) maintains that "a standard way of conceptualizing this distribution of length is to suppose that the vowel and consonant durations co-vary to try to keep the duration of a larger constituent

such as the syllable or foot relatively constant, i.e. vowel and consonant durations compensate for each other."

Kuijpers (1993) has studied several temporal aspects which characterize the developmental stage of children's speech in Dutch. The researcher has tried to investigate how children become conscious of the temporal aspects of their speech and develop their speech in accordance with the adult model. Three pilot studies have been made to examine the way segmental durations are realized and how they affect one another. In the first two pilot studies, for instance, syllable duration, vowel duration and initial voiced/voiceless plosives contrasts within the speech of two Dutch children at the ages of two years and three months, and two years and six months have been detected. In the third pilot study, the development of voicing contrasts of plosive consonants /p,b/ and /t,d/ has been dealt with. For this purpose, a group of children at the ages of one year and a half, and three years and nine months has been tested. Furthermore, a production experiment has been carried out in order to inspect medial consonant voicing contrasts (e.g. /p/ vs. /b/ and /t/ vs. /d/) as well as vowel length contrasts, i.e. short versus long vowels. The plosives closure durations have been measured when occurring in spontaneous; yet, controlled speech utterances spoken by children at the ages of four, six and twelve years old, in addition to adults.

The results reveal that closure durations of voiced plosives are relatively shorter than those of voiceless plosives. Besides, it is observed that adults exhibit compensatory patterns, i.e. they have produced roughly longer vowels before voiced consonants than before voiceless ones so that the overall duration of /-VC-/-structure is kept constant. It is also found out that temporal compensation is gradually acquired by children at the ages of four and six years. It develops from the stage where no evidence of timing compensation is found towards the stage of partial compensation, and then, the final stage of complete temporal compensation similar to that of the adult.

In a recent study, Hajek (2003) maintains that there is a negative relationship between vowel and consonant durations. Such a type of relationship is also known

'V/C complementation'. Hajek (ibid) attempts to investigate V/C as complementation in one of the dialects spoken in Northern Italy, namely Bolonese. It is claimed that this dialect reflects well-established V/C complementation patterns. Furthermore, it is remarked that traditional Bolonese orthography supports such a claim by doubling all simple consonants after short tonic vowels. Contrary to that, short consonants after long vowels are never orthographically doubled. Apparently, this study is intended to examine the complementation phenomenon by making a comparison between the duration of the post-vocalic consonant and that of short/long preceding vowels. Therefore, seven minimal or semi-minimal pair words exposing durational differences between the vowels and the consonants are prepared. For example, /pa:na/ 'cream' versus /pan:a/ 'feather'. The wordlist is read by three native speakers of Bolonese, and the durations of 'tonic vowels' and 'post-tonic' consonants have been measured (Hajek,ibid:1-2). The results demonstrate that the vowel duration equals to two thirds of the overall duration of the /V:C/-sequence. In the event of /VC:/-sequences, the vowel constitutes less than one third and the consonant is slightly more than two thirds of the overall duration of the /VC:/-sequence (Hajek,ibid:3).

Nagai (1996) has acoustically studied the compensatory effect which takes place between a voiced consonant and a pre-consonantal vowel through syllabic boundaries by inspecting the voicing effect of the second consonant occurring within the word structure C1V1.C2V2. An experiment is designed to identify the levels of English learners of Japanese so that their achievements, in the course of the learning process, are evaluated. A wordlist containing six minimal pairs of nonsense words is arranged. The words are spoken within a carrier sentence by twelve subjects, i.e. four native speakers of Japanese, four British elementary learners of Japanese and four British advanced learners of Japanese. Each sentence is read five times (Nagai,ibid:2-3). The results indicate that, for native speakers of Japanese, voiced C2 duration appears to be shorter than that of voiceless C2, but for elementary learners, voiced C2 duration does not appear to be shorter than that of its voiceless cognate. With regard to advanced learners, the results come

midway between those of the former two parties, namely the native speakers of Japanese and British learners of Japanese at the elementary level (Nagai,ibid:5). Moreover, the overall word duration is relatively kept constant in spite of voicing distinctions.

Throughout this experiment, Nagai (ibid) has affirmed the general contention that voiced consonants are 'intrinsically' shorter than their voiceless counterparts, and that this shortening is compensated for by the lengthening of the preceding vowel. This type of 'compensatory segmental adjustment' can be clearly identified in the speech of native speakers of Japanese and British learners at the advanced level, whereas learners of Japanese at the elementary level do not reveal such a pattern probably due to "their insufficient phonological system, which is expected to cause the lengthening of devoiced consonants" (Nagai, ibid:8).

Nagai (ibid) has also advocated that the learners' achievement can be judged on the basis of their ability to "show the universal-looking lengthening effect of voicing. It might be one of the elementary learners' targets to achieve more natural utterances" (Nagai,ibid:8). A further finding is that an evidence of temporal compensation can be noticed across boundaries, i.e. C2 voicing in the second mora affects the preceding V1 duration which lies at the boundary of the first mora. This experiment shows a conspicuous fact that "the compensatory timing control of Japanese is realized not only inside of a single CV sequence but also across the adjacent CV units to keep the total word duration consistent" (Nagai,ibid:9). This denotes that timing compensation effect is a natural feature of Japanese speech, for it is noticed in the speech of Japanese native speakers and British advanced learners of Japanese as well. That is to say, these two parties expose the same compensatory pattern which is not revealed by elementary learners of Japanese.

As it was mentioned previously, Braunschweiler (op.cit.) has examined several temporal aspects in German, such as vowel duration, closure and release durations in disyllabic words. The words include the vowels /a/ versus /a:/ preceded by the plosives /p,b/, /t,d/, /k,g/. The results disclose that both long and short vowels exhibit a compensatory lengthening effort before voiced plosives.

Moreover, it is found that closure durations of voiced plosives are shorter than those of their voiceless counterparts. Yet, the difference is not attributed to the duration of the preceding vowel. In other words, voicing contrasts are not identified as a function of the lengthening of the duration of the preceding vowel.

van Leyden (2002) has, in an extensive experimental study, investigated the relationship between vowel and consonant durations in three Scottish dialects, namely Shetland, Orkney, Standard Scottish English. More specifically, he has examined the correlation between vowel and final consonant durations in these dialects. A list containing 107 monosyllabic words spoken in the three dialects is set out. In order to inspect the effect of the preceding vowel on the duration of word-final consonant, three consonants are chosen to occur in word-final position /r, t, m/ which are preceded by a set of 17 vowels including seven front vowels, six back vowels and four diphthongs. Conversely, for the purpose of examining the effect of word-final consonant on the preceding vowel duration, two vowels are selected /I,i:/ which are examined in all possible consonant contexts. Almost all words begin with a voiced plosive to achieve uniformity as well as to facilitate measurement. However, in the event that no such words are available, monosyllabic words initiated by a voiceless fricative or a nasal are selected. The words are embedded in a carrier sentence and spoken by 13 native speakers of Shetland (6 males and 7 females), 12 native speakers of Orkney (6 males and 6 females), in addition to 12 native speakers (6 males and 6 females) of Standard Scottish English. The measurements obtained from (C)VC words spoken by Shetland speakers indicate that there is a clear inverse relationship between vowel and final consonant durations, i.e. the longer the vowel, the shorter the final consonant. This definitely signifies a 'fair degree' of compensation in the duration of the word final consonant to compensate for the duration of the preceding vowel. For example, a change in vowel duration of 100 ms. requires a negative change of 49 ms. in final consonant duration (van Leyden, ibid: 6-7).

In comparison with the results of Shetland speakers, those of Orkney speakers show that there is 'less clear-cut' association between vowel and

consonant duration. Still, there exists a certain amount of timing compensation exposed by the final consonant duration variation. It is also found that the change in vowel duration of 100 ms. brings about an inverse change of 29 ms. in word-final consonant duration. So, the timing compensation effort is less evident in Orkney than in Shetland (van Leyden,ibid.:9-10). Concerning the results of Standard Scottish English speakers, they also demonstrate that there is a slight inverse correlation between vowel and consonant durations. Consequently, a change of 100 ms. in vowel duration enlists an inverse change of 30 ms. in consonant duration (van Leyden,ibid:11-12).

Briefly, the three dialects signify a negative relationship between vowel and consonant durations though in different degrees. For instance, in Shetland dialect there is a significant inverse correlation between vowel and final consonant durations. Conversely, Orkney and Scottish Standard English dialects reveal slight (weak) correlation between vowel and final consonant durations. In other words, Shetland dialect shows stronger compensatory effect than those of Orkney and Standard Scottish English (van Leyden,ibid:14).

In Arabic, researchers have made attempts to study the phenomenon of temporal compensation. Port et al. (op.cit.) have performed a comparative experiment to find out whether a compensatory effect takes place between the durations of the adjacent vowels and consonants in both Arabic and Japanese. With reference to the Arabic experiment, a set of words containing the consonants /t, d, r/ preceded by a stressed vowel is prepared. The words are recorded at three different tempos, viz. slow, neutral and fast. These words are spoken by five Arabic native speakers. The findings display that the vowels /a/ and /aa/ which occur before the voiced plosive /d/ are longer than those occurring before the voiceless plosive /t/ though the difference between /t/ and /d/ is found to be very small. It is found that the two vowels, viz. /a/ and /aa/, lengthen by 13 ms. at the neutral speech rate, but the same vowels tend to be much longer when the tested words are spoken at the slow tempo. The results also yield that the voicing feature of the medial consonant affects the duration of the preceding vowel

and the VOT of the initial consonant. Port et al. (ibid:239) state that "changing the voicing of medial stop does not significantly affect the duration of the stop itself in Arabic, but does affect the duration of the preceding vowel as well as the VOT of a stop that is two segments away." What is more, the voiced flap /r/ shows greater durational variation. It is influenced by the preceding vowel which greatly lengthens at the expense of /r/ duration. For example, the preceding vowel lengthens by 10 ms., while /r/ shortens by 30 ms. at the neutral tempo. On the basis of the results, it is deduced that Arabic shows little evidence of temporal compensation between the preceding vowel and post-vocalic consonant durations (Port et al.,ibid:240).

Contrary to the findings of the Arabic experiment concluded by Port et al. (ibid.), Japanese shows clear-cut compensatory correlation between vowels on both sides of the consonant. Since Japanese is considered as a syllable-timed language, /CV/-sequences are expected to be equal in terms of duration. The consistency of duration is attributed to timing compensation mechanism. An experiment has been designed. Disyllabic words containing the longest vowel /a/, the shortest vowel /u/ as well as four consonants ranging from the longest fricative /s/ to the shortest flap /r/, viz. /s, t, d, r/, are prepared. All the words begin with the plosive /b/. The words are read within a carrier sentence by 13 Japanese native speakers. The results point out that there is a negative relationship between the initial plosive and the following vowel duration. With respect to the medial plosive voicing effect, it is confirmed that there are "strong complementary effects between the timing of the stop constriction duration and both adjacent vowels" (Port et al., ibid:243). For example, the adjacent vowels on both sides of the voiced alveolar plosive /d/ are found to be significantly longer than those on both sides of the voiceless plosive /t/. Obviously, the vowels in Japanese show a tendency to lengthen before and after voiced consonants, while they tend to shorten before and after voiceless ones.

Port et al. (ibid.:244-245) have compared the results of both experiments. The comparison reveals that, in Japanese, /d/ is significantly shorter than /t/. More to the point, the neighbouring vowels on both sides of a consonant make

up for the variations in consonant duration to nearly the same extent in Japanese. Contradictorily, in Arabic, the durational difference between /t/ and /d/ tends to be less than that in Japanese. As a result, it is only the preceding vowel which is affected by the following consonant duration. Since the languages under investigation show different temporal compensation patterns in similar contexts, this evidently indicates that timing compensation effects are language-specific and should be learned by the speakers of the language.

Recently, Hassan (2003) has also carried out a comparative study to investigate temporal compensation correlation in /CV:C/ and /CVC:/ structures in both Arabic and Swedish. Wordlists for each language have been prepared and read within a carrier sentence by native speakers of the two languages. The measurements prove that there is a very significant durational difference between the preceding vowel and the post-vocalic consonant in Swedish. That is to say, long vowels are followed by short consonants, whereas short vowels are followed by long consonants. In as far as Arabic is concerned, the results manifest that there is insignificant difference between the duration of the preceding vowel and the following consonant. Thus, it is inferred that Arabic reveals negligible timing compensation effort (ibid:47-48). Nevertheless, Swedish signifies a clear-cut correlation (temporal compensation) between the durations of the preceding vowel and the following consonant.

# **Chapter Four**

# The Experimental Design

#### 4.1 Introduction

Every speech sound has a characteristic duration. That is to say, every individual sound has its own duration which differs from that of another. However, during their everyday vocal communication humans produce speech sounds, to some extent, with insignificant durational differences. Morton (1984:39) states that "speech segments vary considerably in length, but human beings are relatively consistent in keeping the audio length of indivisual segments nearly the same." This physical feature is basically studied within the zone of acoustic phonetics.

Acoustic phonetics, according to Roach (2002:3), is "the study of the physics of the speech signal: when sound travels through the air from the speaker's mouth to the hearer's ear it does so in the form of vibrations in the air. It is possible to measure and analyze these vibrations by mathematical techniques." In fact, acoustic phonetics deals with a number of phonetic features such as duration, intensity, fundamental frequency, amplitude, etc. It also investigates the correlation between the speech sounds and the articulatory apparatus responsible for their production (Roach,1991:185; Roach,op.cit.:3). Moreover, acoustic studies "provide a clear, objective datum for investigation of speech" (Crystal,1997:5).

As it is mentioned above, segmental duration is tackled through this branch of phonetics, viz. acoustic phonetics. Thus, the present research aims at investigating the relationship between vowel and consonant durations, i.e. how they compensate for their durational variations in order to maintain duration consistency (temporal compensation phenomenon). This goal is achieved by experimentally examining a specified amount of sample data in MSA. The durations of the adjacent vowel and consonant are measured by means of the obtained relevant spectrograms. For more clarification, the whole experimental design is discussed in detail in this chapter.

#### .4.2 Method

It is worth remarking that the researcher followed a methodology nearly similar to that adopted by Ghalib (1984) in so far as the technique required for carrying out the experimental part of the present study is concerned.

# 4.2.1 Selection and Categorization of Data

As it was pointed out in (§4.1), the present study is intended to investigate the timing compensation process, which takes place between vowel and consonant relative durations. Thus, a list comprising (40) minimal pair disyllabic words was prepared. Each pair of words displays a morphological structure revealing either short/long vowel contrasts and/or single (short)/geminate (long) consonant contrasts.

The words were chosen in such a way that almost most of the consonantal types occurring in word medial position were existent, i.e. they can be plosives, fricatives, affricates, nasals, flaps, laterals and approximants. In word-initial position, however, plosive consonants were, sometimes, excluded in order to avoid the difficulty of identifying the onset of an initial plosive when acoustic measurements were made.

Regarding vowels, only the short vowel /a/ and its long counterpart /aa/ were employed for the purpose of comparing the data and exposing the reciprocal compensatory effort that dominates the durations of the adjacent vowel and consonant.

Additionally, each word was spoken within the carrier sentence /?iqra? ------sitta marraat/ 'Read ------ six times'. It is noteworthy that the carrier sentence begins with the plosive /?/ despite the fact that it shows up difficulty of specifying its onset when segmentation procedure is performed. This can be attributed to the morphological structure of the imperative form of verb in the Arabic language on the grounds that in one of its forms, the Arabic imperative verb form is most frequently formulated with an initial /?/ as in the case of the verb /?iqra?/ 'read'.

As for the selected material and their contrasts, they can be classified into four categories. Every category represents one of the following four patterns:  $/ fa = \frac{1}{a} - \frac{1}{a} = \frac{1}{a} =$ 

## 4.2.1.1 <u>Category I</u>

The first category contains minimal disyllabic words having the structures /'CVCVC/ vs. /'CVCCVC/, i.e. the words are of the patterns /'faSal/~/'faSSal/. Each element of any minimal pair has stress to be placed on the first syllable. Table (4.1) illustrates the sample data of the first category.

Table(4.1): The Word Sets of the Patterns / fa al/~/fa Included in Category I

The Pausal Form		The Pausal Form
	/'CVCVC/	/'CVCCVC/
/'fataħ/	'he opened'	/'fattaħ/ 'he unfolded'
/'ðakar/	'he mentioned'	/'ðakkar/ 'he reminded'
/'waqa\$/	'he fell down'	/'waqqa\forall 'he signed'
/'nafað/	'it penetrated'	/'naffað/ 'he carried out'
/'ħa∫ad/	'he gathered'	/'hassad/ 'he gathered' (emphatic)
/ˈħadaθ/	'it happened'	/ˈħaddaθ/ 'he talked to'
/'naðam/	'he composed'	/ˈnaððam/ 'he organized'
/'χazan/	'he stored'	/'xazzan/ 'he stored' (emphatic)
/ˈradʒaʕ/	'he came back'	/'radzdzas/ 'he returned'
/'ħamal/	'he carried'	/'hammal/ 'he loaded'

#### 4.2.1.2 <u>Category II</u>

The second category aims at making a comparison between two sets of disyllabic words of the patterns /'fa5\fa1/~/fa5\fa1/: the first set consists of (10) words whose first and second syllables have the short vowel /a/, whereas the words of the second set contain the long vowel /aa/ occurring in the second syllables. They also contain voiceless and voiced geminate consonants occurring word medially. To put it differently, the words of the first set has the structure /'CVCCVC/, and stress is placed on the first syllable, while the second set of words has the structure /CVC'CVVC/, and primary stress is positioned on the second syllable. See table (4.2) for more illustration.

Table(4.2):The Word Sets of the Patterns /'fassal/~/fas'saal/ Included in Category II

The Pausal Form		The Pausal Form
	/'CVCCVC/	/CVC'CVVC/
/'fattaħ/	'he unfolded'	/fat'taaħ/ 'proper noun'; 'opener'
/'Saţţar/	'he perfumed'	/Saţ'ţaar/ 'perfumer'; 'spicedealer'
/'naʃʃaf/	'he dryed'	/na∫'∫aaf/ 'dryer'
/'raħħal/	'he caused to leave'	/raħ'ħaal/ 'traveller'
/'haddam/	'he destroyed'	/had'daam/ 'destructive'
/'xazzan/	'he stored'	/χaz'zaan/ 'reservoir'
/'ħammal/	'he loaded'	/ħam'maal/ 'porter'
/'ħallaq/	'he flew'	/ħal'laaq/ 'barber'
/'Sallam/	'he taught'	/Sal'laam/ 'expert'
/'Sarraf/	'he defined'	/Sar'raaf/ 'fortune-teller'

### 4.2.1.3 Category III

The words within this category are of the patterns /'fasal/~/faasal/. They fall into two groups: the first group consists of (10) words of the structure /'CVCVC/; the second category also comprises (10) words having the structure /'CVVCVC/. Both groups have primary stress on the first syllable. Table (4.3) displays the sample data concerned.

Table(4.3):The Word Sets of the Patterns /'fa\al/~/'faa\al/ Included in Category III

The Pausal Form		The Pausal Form
	/'CVCVC/	/'CVVCVC/
/ <b>'</b> ʃaţar/	'he halved'	/'ʃaaţar/ 'he shared equally with'
/'naqaʃ/	'he engraved'	/'naaqaʃ/ 'he discussed'
/ˈṣafaħ/	'he excused'	/ˈṣaafaħ/ 'he shook hands with'
/'ħasab/	'he calculated'	/'haasab/ 'he setteled an account with'
/'waṣal/	'he arrived'	/'waasal/ 'he continued'
/ˈsadaq/	'he told the truth'	/'saadaq/ 'he made friends with'
/'nazal/	'he descended'	/'naazal/ 'he clashed with'
/'∫a <b>r</b> al/	'he occupied'	/ˈʃaaʁal/ 'he drew attention'
/ˈradʒaʕ/	'he came back'	/ˈraadʒaʕ/ 'he reviewed'
/'samaħ/	'he allowed'	/'saamaħ/ 'he forgave'

# 4.2.1.4 <u>Category IV</u>

In a similar vein, the fourth category includes two sets of words of the patterns /'faa\al/~/fa\al/: the first set is made of words having the structure

/'CVVCVC/ and stress is positioned on the first syllables, while the second set contains (10) words of the structure /CVC'CVVC/ whose second syllables receive primary stress. The fourth category is illustrated in table (4.4).

It is worth mentioning, however, that after performing the recording, segmentation and measurement techniques, the researcher and her supervisor felt that the data exceeds the required amount within the scope of this study; therefore, the data was squeezed into three main groups. These are illustrated in tables (4.5-4.7).

Table(4.4): The Word Sets of the Patterns /'faa\al/~/fa\\'\al/ Included in Category IV

The Pausal Form		Th	ne Pausal Form/
	/'CVVCVC/		CVC'CVVC/
/'saabaq/	'he raced with'	/sab'baaq/	'forerunner'
/ˈsaabar/	'he tolerated'	/sab'baar/	'cactus'
/ <b>'</b> aadar/	'he left out'	/ <b>k</b> ad'daar/	'perfidious'
/'naaqa <b>∫</b> /	'he discussed'	/naq'qaa∫/	'engraver'
/'naaza\$/	'he quarrelled'	/naz'zaa\$/	'tending'
/'χaala <b>ţ</b> /	'he mixed with'	/χal'laaţ/	'mixer'
/'Saalam/	'world'	/Sal'laam/	'expert'
/'zaawal/	'he pursued'	/zaw <sup>'</sup> waal/	'fading away'
/'Saawad/	'he reverted to'	/\faw'waad/	'lutist'
/'saajar/	'he complied with'	/saj'jaar/	'planet'

**Table(4.5):The Word Sets of the First Group** 

The Pausal Form		The Pausal Form
	/'CVCVC/	/'CVCCVC/
/'fataħ/	'he opened'	/'fattaħ/ 'he unfolded'
/'ðakar/	'he mentioned'	/'ðakkar/ 'he reminded'
/'nafað/	'it penetrated'	/'naffað/ 'he carried out'
/'ħa∫ad/	'he gathered'	/'ha∫ad/ 'he gathered' (emphatic)
/'ħadaθ/	'it happened'	/'ħaddaθ/ 'he talked to'
/'naðam/	'he composed'	/ˈnao̞o̞am/ 'he organized'
/'χazan/	'he stored'	/'χazzan/ 'he stored' (emphatic)
/'ra <b>d3</b> a\$/	'he came back'	/ˈradʒdʒaʕ/ 'he returned'
/ˈħamal/	'he carried'	/ħammal/ 'he loaded'

**Table(4.6):The Word Sets of the Second Group** 

The Pausal Form			The Pausal Form
	/'CVCCVC/		/CVC'CVVC/
/'fattaħ/	'he unfolded'	/fat'taaħ/	'proper noun'; 'opener'
/'Saţţar/	'he perfumed'	/Saţ'ţaar/	'perfumer'; 'spicedealer'
/ˈraħħal/	'he caused to leave'	/raħ'ħaal/	'traveller'
/'xazzan/	'he stored'	/χaz'zaan/	'reservoir'
/'ħammal/	'he loaded'	/ħam'maal/	'porter'
/'Sallam/	'he taught'	/Sal'laam/	'expert'
/'Sarraf/	'he defined'	/Sar'raaf/	'fortune-teller'

**Table(4.7): The Word Sets of the Third Group** 

The Pausal Form		The PausalForm
	/'CVCVC/	/'CVVCVC/
/'naqa <b>ʃ</b> /	'he engraved'	/'naaqaʃ/ 'he discussed'
/'ħasab/	'he calculated'	/'haasab/ 'he setteled an account with'
/'waṣal/	'he arrived'	/'waasal/ 'he continued'
/'nazal/	'he descended'	/'naazal/ 'he clashed with'
\ <b>J</b> a <b>R</b> al\	'he occupied'	/'ʃaaʁal/ 'he drew attention'
/ˈradʒaʕ/	'he came back'	/ˈraadʒaʕ/ 'he reviewed'

### 4.2.2 The Subjects

The recordings were performed by 10 (five males and five females) Arabic native speakers including the researcher. The subjects were of different ages; the ages of male subjects ranged between (25-35), whereas the ages of the female subjects ranged between (20-26) years. All the participants had no articulatory or hearing defects. They were born in the city of Basrah where they are still living. They all speak the typical dialect of Basrah. Moreover, they hold different degrees of educational levels.

# 4.2.3 The Recording Technique and Instrumental Set-up

A list of the isolated (5 dummies and 40 words) minimal pair words was prepared and randomly arranged into two scripts. Each script was randomized anew in accordance with the morphological structures of the word categories. Randomization helps keep tone variability during the recording sessions, i.e. it is intended to avoid uttering words monotonously (Ghalib,op.cit.:153). As a result, each speaker accomplished two recording sessions. Later on, the participants were instructed to read the words within a carrier sentence (§ 4.2.1,p.63). Similarly, the

sentences were differently arranged over two lists, and accordingly, each speaker performed two recording sessions. Furthermore, the participants were asked to repeat any words pronounced incorrectly.

The corpus of the data described above was recorded by using an external, highly sensitive (head-mounted) microphone attached to headphones (type: Somic CD-750 M.V.) which were useful in listening, and consequently identifying the onsets and offsets of certain speech sounds with a range of sensitivity at (110 db) and frequency at (20-20000 Hz). Besides, it was provided with volume meter to control sound loudness. Both the microphone and the headphones were directly connected to a computer which was a Pentium IV (type: Art) with a CPU at (1.7) GHz, RAM (128) MB, hard disk (40) GB, and with a video card (32) MB. The computer was also connected to two loud speakers (type: E-power BS-250), and a scroll mouse (type: Action3DAM-878). The recordings were carried out in a quiet room. Every participant was seated before the computer. The headphones were placed on his/her head and the microphone was positioned in front of his/her mouth at a distance of 4 cm. Each recording session lasted for roughly (45) minutes with several intervening breaks. After recordings had been made, they were immediately stored on the hard disk.

# 4.2.4 The Computer Software Package

The recorded data was converted into a computerized input by employing a computer software<sup>1</sup> called Speech Filing System (version 1.33) (Huckvale,2002). It allows recording speech materials at a speech rate (16000) Hz in order to create wide-band spectrograms accompanied by waveform graphs required for extracting the acoustic measurements of the segmental duration.

### 4.2.5 Segmentation and Measurement

It is well known that speech sounds do not occur in isolation. Instead, they are used within certain phonetic contexts in order to construct meaningful structures and convey information. This juxtaposition of speech sounds may affect the articulatory posture of the adjacent segments within certain streams of speech. However, it is found that it is difficult to meticulously segment a speech stretch, since the actions of the vocal organs responsible for producing the segments of that speech stretch gradually become interrelated with each other. In other words, the transition from one segment to another adjacent one requires a gradual movement from one articulatory position to another one (O'Connor,1973:67). In this respect, Raphael et al.(1980:297) mention that there is no direct, clear-cut acoustic boundaries between segments in the speech stretch because of the 'phonetic information' overlapping. O'Connor (op.cit.:69), for his part, contends that "when we say that it is extremes of articulatory movement which determine segments, that is not the same thing as saying that the extreme positions determine our perception of the segments."

However, for Brosnahan and Malmberg (1970:77) segmenting a continuous speech stream like [hɔ:s], which exposes no breaks or points of segmentation, can be done by depending only on 'features observable' in that sequence. They adopt Pike's segmentation procedure, and consider it as a successful one. In accordance with this procedure which is based on articulatory material, the vocal organs have basic types of movement: first, the 'closing movement' which brings about "a closure or narrowing at some point or relatively small section of the vocal tract. Such a closure or narrowing is termed a stricture." In addition, the top of the stricture, 'crest of stricture', is a position where the vocal tract comes to a relatively closing state. Second, the opening movement makes "a stricture of greater openness in the vocal tract" (Brosnahan and Malmberg, ibid:77). Moreover, the lowest point of the stricture, 'trough of stricture', is a position where the vocal tract comes to a state of openness. In consequence, 'each crest and trough'

is considered to be as the centre of a segment in the sequential articulations within a speech stream to the extent that the number of segments in a speech sequence is parallel to the number of 'crests' and 'troughs' within the same sequence (Brosnahan and Malmberg,ibid:78). Nonetheless, Pike's procedure of segmentation fails to indicate the onsets and offsets of segments.

Joos (1948), as cited in Brosnahan and Malmberg (ibid:78-79), presents a further procedure for the purpose of segmenting a stream of speech, i.e. it is based on certain features as being recognized in speech sound spectrograms. These features can be classified into two types: the first type implies the existence of periods within the speech continuum where speech sounds frequencies and intensities are considerably variable and these are labelled as 'segments'; the second type of features implies the existence of periods shorter than those in the first type. That is to say, there is a 'rapid change' in these frequencies and intensities. These are known as 'transitions'. Additionally, these 'segments' and 'transitions' occur alternately within a speech sequence. For instance, the spectrogram of the aforementioned word [hat:s] exposes a transition for 'a very short period' of instant conversion from silence to an activity of wide range of frequencies. The maintenance of the frequencies in this period is considered to be a segment; then, this segment is followed by another transition and so on and so forth (Brosnahan and Malmberg, ibid:79). Nevertheless, the boundaries of these segments and transitions are not clear-cut. The following fig.(4.1) displays the spectrogram of the word in question.

Brosnahan and Malmberg (ibid:79) add that there is a further segmentation procedure which tends to be generally used by phoneticians. This procedure essentially depends on comparing and contrasting an articulatory sequence with other sequences. For instance, [hɔ:s] can be compared with sequences like 'course, gorse, hearse', etc. This suggests that the [hɔ:s] stream of speech consists of three portions. The first portion occurs initially in 'hearse'; the second exists medially in 'gorse', and the third is positioned finally in 'course'.

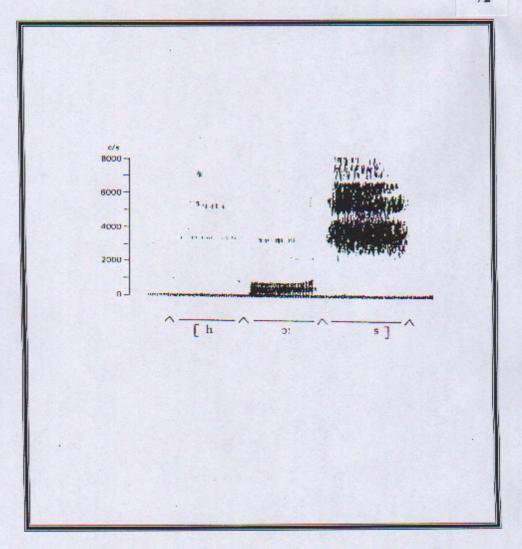


Fig. (4.1): A Wide-Band Spectrogram of the Word [hD:s] 'horse'

Displaying the Arrowheads Marking the Transitions
and the Lines Extending Along the Intervening
Segments

After Brosnahan and Malmberg (1970).

Notwithstanding, some phoneticians (e.g. Peterson and Lehiste, 1960; Abercrombie, 1965; Liberman et al., 1967) believe that it is difficult to segment stretches of speech unambiguously in ways that facilitate the determination of the boundaries where a certain sound commences and where it ends. Peterson and Lehiste (op.cit.:694) state that segmenting speech sequence "has long been and continues to be a major problem in speech analysis." This situation can be attributed, as Ghalib (op.cit.:157) reports, to the vocal tract activity which comprises intricate series of movements. In this connection, Abercrombie (op.cit.:123) maintains that a certain speech sound posture may not exactly coincide with the vocal apparatus in motion. Thus, he adopts 'a parametric approach' which he considers as a more effective approach than the segmental one. Abercrombie (ibid:123) states that "the division of speech into phonemerepresenting segments represents a division at right angles to the time axis, whereas the division into parameters is a division parallel to the time axis." Liberman et al.(op cit.:441) point out to the complexity of segmenting speech sound sequences correlating such a complexity to the point that "successive phonemes are most commonly merged in the sound stream." Still, the determination of segmental boundaries may, in some events, reveal less difficulty, as in the case of vowels. House and Fairbanks (1953:107) claim that "the identification of the beginning and end of a vowel surrounded by consonants is an arbitrary act that is both difficult and artificial. Location of these points was aided by the relative clarity with which they are shown in sound spectrograms."

In the present experiment, the segmentation procedure employed basically depends on the visual representations of speech sounds, viz. wide-band spectrograms and waveform graphs, which indicate the vocal folds activity. They were manipulated to specify the segmental onsets and offsets which are necessary to calculate durational acoustic measurements. In events where segmentations on wide-band spectrograms are problematic or difficult to be performed, the waveform traces serve as a helpful cue to identify the consonantal and vowel boundaries. More precisely, vocal folds activities are useful in showing up the articulatory points for the onsets and offsets of the segments under investigation.

Practically, durational measurements are taken directly from the spectrograms displayed on the screen of the computer. This technique provides the possibility of manipulating two vertical coloured cursors at the same time in order to determine the onset and offset of the segment on both the waveform and the spectrogram. The first cursor, in green colour, helps show the initiation (onset) of the segment; while the second cursor, in blue colour, is used to indicate the coda (offset) of that segment. See fig.(4.2). In fact vowels tend to be the most easiest segments to have their boundaries be determined. Ng (2004:6) justifies by commenting that:

Since vowels have no closure or aspiration according to their properties, onset of a vowel is considered to be at where voicing, the high-energy part, begins. If another phoneme follows, then the ending bound is at a point where the high-energy frequency starts to drop.

For example, the boundaries of the vowels /a/ and /aa/ on wide-band spectrograms are pointed out by placing the green cursor at the place where a preceding consonant ends and the following /a/ or /aa/ begins. Simultaneously, the blue cursor is located at the position where the vowel ends and the following consonant commences. Figs. (4.3) and (4.4) display the acoustic boundaries of both vowels,viz. /a/ and /aa/.

Contrary to that, the identification of the consonantal boundaries is more difficult to locate than in the case of vowels. Ladefoged (1975:174) argues that such a difficulty can be related to the 'acoustic structure' of consonants which "is usually more complicated than that of vowels." Regarding plosive consonants, it is evident that their articulation involves a 'total occlusion' of the vocal tract; therefore, they are represented by a gap (a period of silence) in the spectrogram (Hagiwara,2004:4). Practically, it was easy to identify the beginning and the end of voiceless and voiced plosives when occurring in word-medial position. For

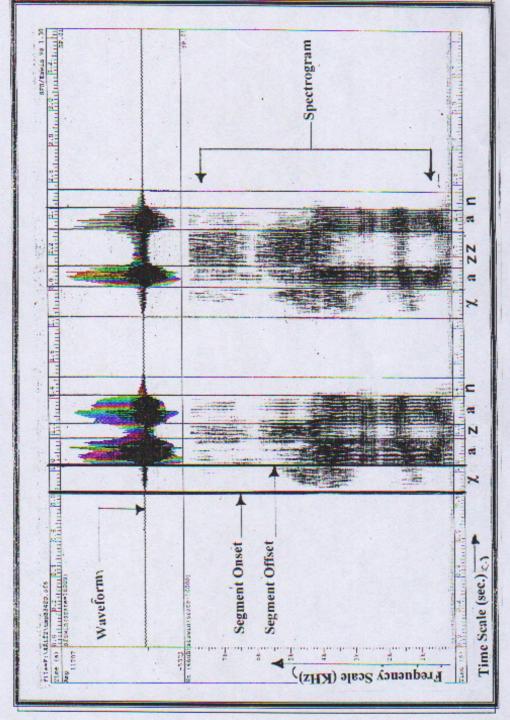


Fig.(4.2): The Spectrogram and the Waveform of the Words /'xazan/--/'xazzan/ Produced in Isolation.

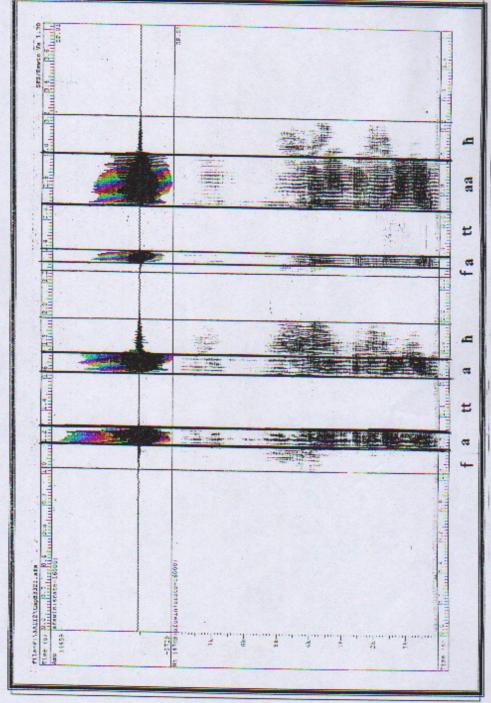


Fig.(4.3): A Spectrogram of the Words / fattah/~/fat'taah/ Produced in Isolation Illustrating the Segmental Boundaries of the Vowels /a/ and /aa/.

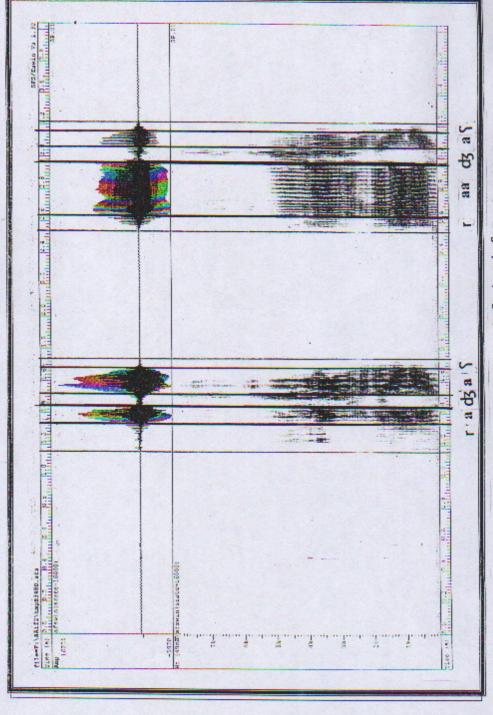


Fig.(4.4): A Spectrogram of the Words /'radga5/~/'raadga5/ Produced in Isolation Illustrating the Segmental Boundaries of the Vowels /a/ and /aa/.

instance, it was easy to determine the boundaries of denti-alveolar plosives /t/ vs. /tt/ and /d/ vs. /dd/ which are illustrated in figs. (4.3) and (4.5).

However, it is difficult to identify the onset of an initial plosive; therefore, it is preferred, as it was previously mentioned (§ 4.2.1,p.63), to select the corpus of data which begins with various consonantal types except plosives to avoid such an obstacle, though the carrier sentence is inaugurated with a glottal plosive /?/ which is considered as an essential morphological component of the imperative form of the verb /'igra?' 'read'. Furthermore, plosives occurring in a word-final position reveal some difficulty in identifying their offsets, for example, /b/ occurring finally in the word /'hasab/~/'hasab/. See fig.(4.6). Conversely, fricatives appear to be the most easiest consonantal type in so far as the determination of their segmental boundaries is concerned. de Lacy (1998:3) says that "the beginning of both voiced and voiceless fricatives was obvious from the appearance of high frequency **noise.**" For instance, the  $/\int/vs./\int\int/$  and /s/ as illustrated in figs.(4.7,8,9,10). Additionally, fricatives are generally characterized by the production of 'frication noise' (Hagiwara, 2004:6). Yet, some fricative consonants occasionally seem to be uneasy to determine their segmental boundaries especially when occurring in initial and final positions, as in the case of the interdental fricative /ð/ displayed in figs.(4.11) and (4.12). For the purpose of overcoming such a problem and ensuring the correctness of segmentation, it is recommended to listen to the beginning and end of the sound in question (Ng,op.cit.:10). This technique was of considerable help for the researcher.

A further difficulty was also faced when an attempt was made to identify the borders of a flap /r/; especially, when it occurred in word-final position. Segmenting a flap and a lateral raises such a difficulty due to the overlapping that takes place between their formants and those of the preceding vowel as illustrated in figs.(4.13) and (4.14). Peterson and Lehiste (op.cit.:698) encounter the same difficulty in their segmentation procedure. They find that /r/ as well as /l/ are the most problematic consonants; particularly, when they occur in word-final position

because "the formant movements were quite smooth, and the establishment of a boundary on the basis of broad-band spectrograms was questionable." In this connection, Ghalib (op.cit.:168) states that "the flapped [r] pronounced intervocalically produced similar traces to those of a preceding or following vowel, i.e. it began with a sharp rise and ended with a steep fall." Furthermore, it has been noticed that it is rather difficult to discern the boundary between a vowel and a following nasal consonant because of the effect of vowel nasalization (Peterson and Lehiste, op.cit.:695). See fig. (4.15). After the required segmentations and measurements were accomplished, the results were displayed and statistically analyzed.

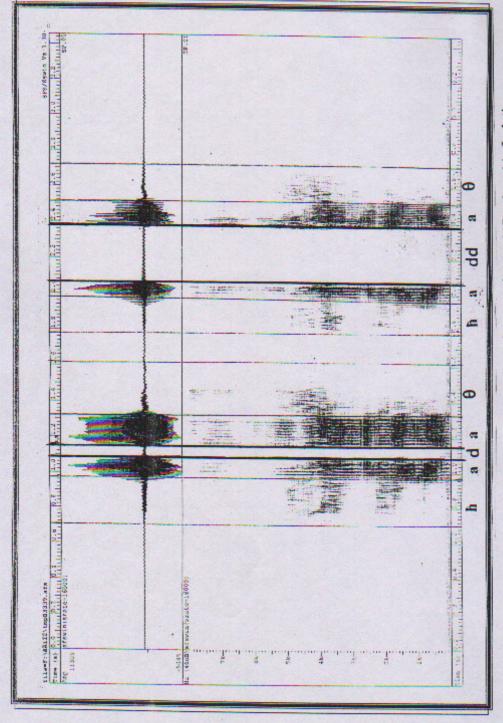


Fig.(4.5): A Spectrogram of the Words /'hadaθ/~/'haddaθ/ Produced in Isolation Displaying the Segmental Boundaries of the Plosive '/d/vs./dd/ Occurring Medially.

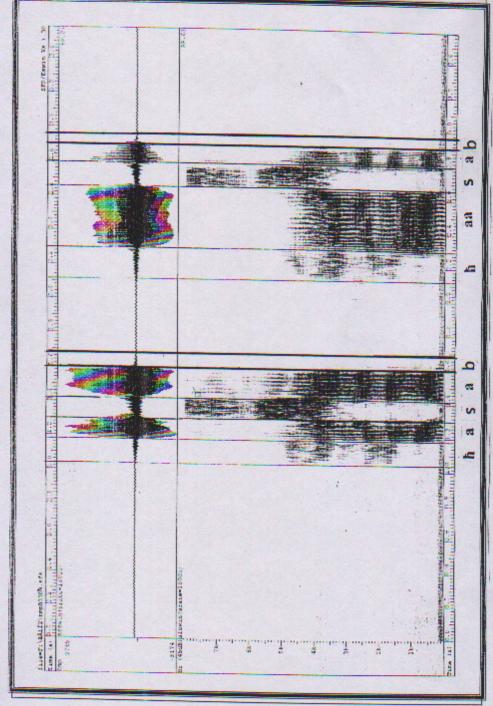


Fig.(4.6): A Spectrogram of the Words /'hasab/~/'haasab/ Produced in Isolation Displaying the Segmental Boundaries of the Plosive /b/ Occurring Finally.

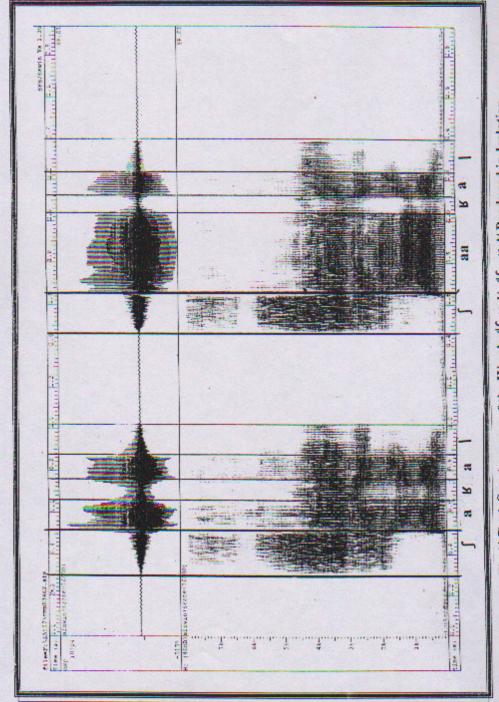
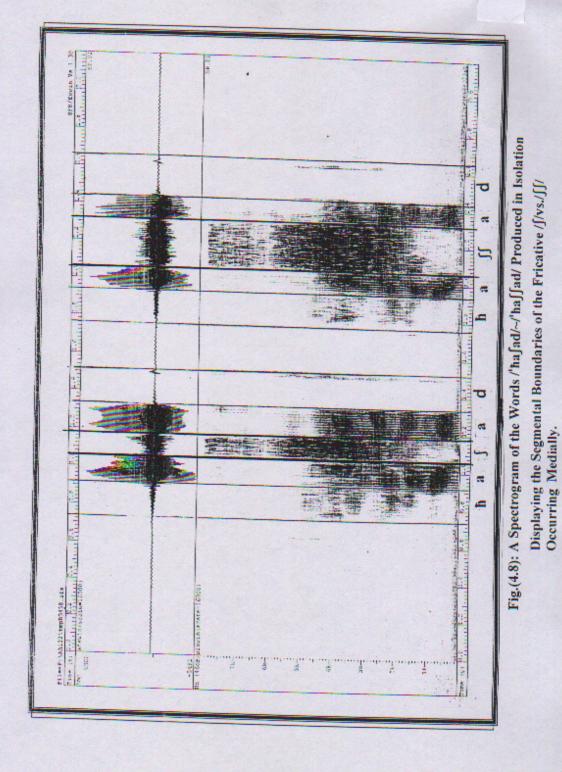


Fig.(4.7): A Spectrogram of the Words /ˈʃaʁal/~/ˈʃaaʁal/ Produced in Isolation Displaying the Segmental Boundaries of the Fricative /ʃ/ Occurring Initially.



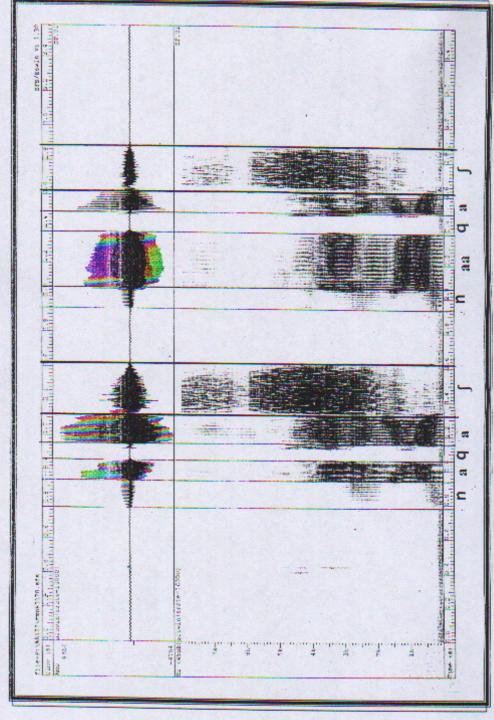


Fig.(4.9): A Spectrogram of the Words /'naqaf/~/'naaqaf/ Produced in Isolation Displaying the Segmental Boundaries of the Fricative /f/ Occurring Finally.

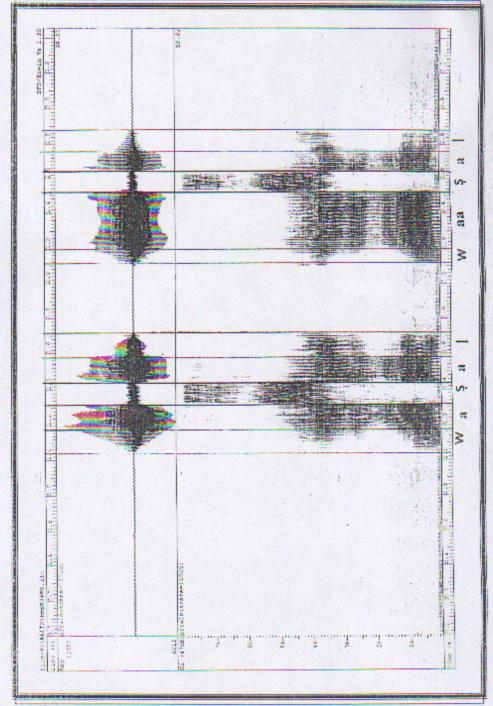


Fig.(4.10): A Spectrogram of the Words /'waṣal/~/'waaṣal/ Produced in Isolation Displaying the Segmental Boundaries of the Fricative /s/ Occurring Medially.

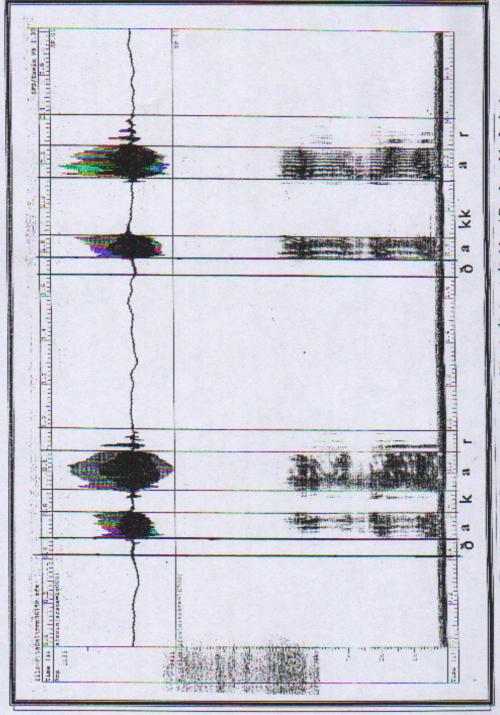


Fig.(4.11): A Spectrogram of the Words /'oakar/~/'oakkar/ Produced in Isolation Displaying the Segmental Boundaries of the Fricative /0/ Occurring Initially.

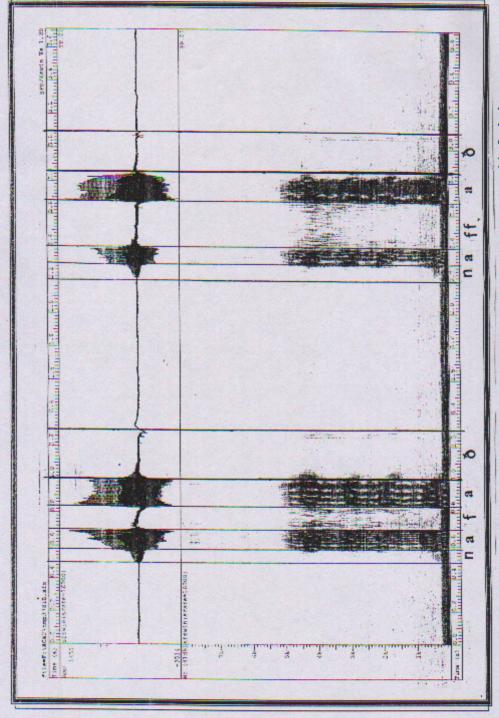


Fig.(4.12): A Spectrogram of the Words /'nafað/~/'naffað/ Produced in Isolation Displaying the Segmental Boundaries of the Fricative /ð/ Occurring Finally.

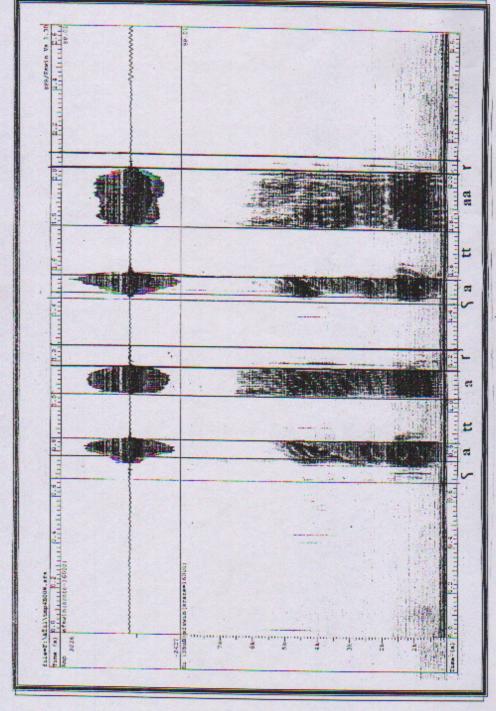


Fig.(4.13): A Spectrogram of the Words /'Saţţar/~/Saţţaar/ Produced in Isolation Displaying the Segmental Boundaries of the Flap /r/ Occurring Finally.

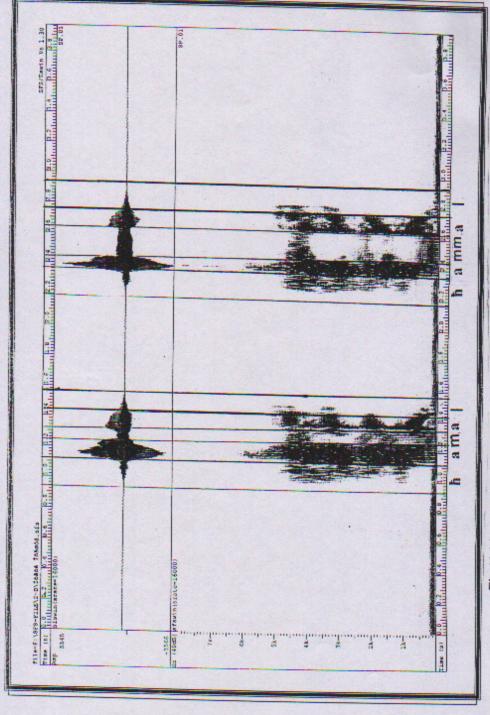


Fig.(4.14): A Spectrogram of the words /hamal/~/hammal/ Produced in Isolation Displaying the Segmental Boundaries of the Lateral /// Occurring Finally.

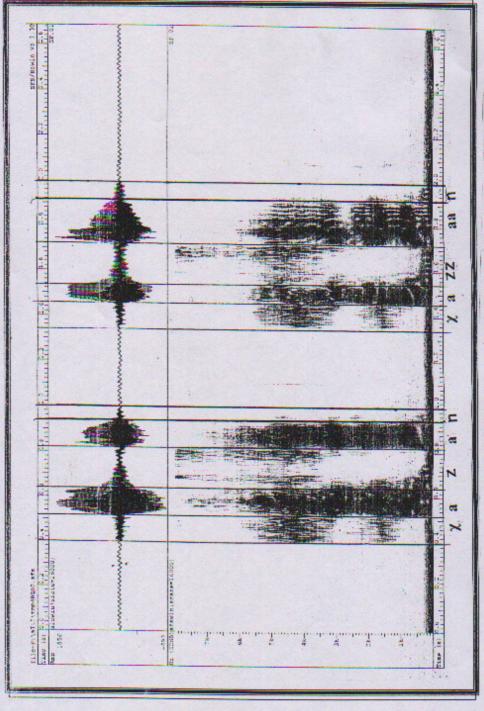


Fig.(4.15): A Spectrogram of the Words /'gazzan/~/gaz'zaan/ Produced in Isolation Displaying the Segmental Boundaries of the Nasal /n/ Occurring Finally.

# **Chapter Five**

# Results, Discussion, Conclusions and Suggestions for Future Research

# 5.1 Introduction

It is well known that statistics represents a feasible tool by means of which a researcher can evaluate the data and elicit the appropriate conclusions related to the phenomenon under investigation. Thus, statistics can be defined as "the branch of scientific method that deals with the collection, description and analysis of data whose occurrences and measurements have been counted" (Cohen,1954:1). More to the point, statistics does not tackle a mere random haphazard of data. Instead, "it handles numerical facts" via different methods, i.e. it expresses facts in terms of numbers (Cohen,ibid: 2).

Thus, the numerical data whether it is quantitive (e.g. the measure of time and speed) or qualitative (e.g. sex and nationality), comprises "the raw material of our subject (statistics); it is from them that our analysis is made, our principles are formulated and conclusions are drawn" (Hays,1970:6). Additionally, accuracy of data as such supports accomplishing valuable statistical analysis and deriving valid conclusions.

This chapter presents the statistical analyses employed as well as the results obtained. Moreover, it yields a detailed discussion of the findings.

# 5.2 The Statistical Treatment

Consequently, throughout the present study the researcher benefited from the statistical analysis that certain statistical parameters (e.g. arithmetic mean and standard deviation) were calculated in addition to the manipulation of two types of tests, viz. the t-test and the analysis of variance (ANOVA for short), which helped eliciting sound explanations in relation to the mechanism of temporal compensation which is the core of the thesis.

Regarding the arithmetic mean, it represents a 'central value' around which scores (measurements) spread, i.e. it is "the center of gravity of distribution" (Cohen, op. cit.: 34). Statistically, the arithmetic mean (mean or average are mutually used ) equals to "the sum of scores or values of a variable divided by their number" (Runyon and Haber, 1976:79). The scores or observations are differently distributed away from the central value, viz. the mean (Cohen,op.cit.:45). This is known as standard deviation (S.D.for short). It is considered as "a measure of scatter of the observations around their mean" (Hill, 1984:70). As a result, the smaller is the standard deviation, the nearer are the measurements to the mean value. In this connection, Hill (ibid:71-72) confirms that "a large standard deviation shows that the frequency distribution is widely spread out from the mean, while a small standard deviation shows that it lies closely concentrated about the mean with little variability between one observation and another." Statistically, standard deviation equals to "the positive square root of variance" (Cohen.op.cit:46).

As it was mentioned earlier, two kinds of parametric statistical tests were used in the present study: the t-test and the ANOVA. The tests were chosen for two main reasons. First, they are deemed to be the most powerful parametric tests due to the "strongest or most extensive assumptions" they assume (Siegel,1956:19). In other words, the more valid are 'the assumptions underlying their use', the more powerful is the test in order to reject the null hypothesis (H<sub>o</sub>) when it is false (Siegel, ibid). Additionally, there are several conditions which must be accomplished where the parametric tests (t-test and ANOVA) can be applied. These are determined literally by Siegel (ibid) as follows:

- 1. The observations must be independent.
- 2. The observations must be drawn from normally distributed populations.
- 3. These populations must have the same variance, i.e. they must have a known ratio of variance.
- 4. The variables involved must have been measured in at least an interval scale.

More to the point, the availability of these conditions indicates 'the meaningfulness of the probability statement' achieved by performing the parametric tests in question (Siegel,ibid:20).

Second, the use of the tests mentioned above allows comparing the means of two groups (t-test) or more than two groups (ANOVA). Since the experimental measurements of the present experiment presupposes that the 'observations' or 'scores' are normally distributed and measured in an interval scale, i.e. "the distances between any two numbers on the scale are of known size" (Siegel,ibid:26), the t-test is used. It is manipulated for the purpose of testing the difference between the means of independent samples (Pollard,1972:104; Lindsay,1997:86).

Statistically, the t-test can be accomplished by dividing "the difference between the means by a measure of dispersion" (Lindsay,ibid). Hence, the greater the difference between the means, the easier it will be to refute the null hypothesis (H<sub>0</sub>). Actually, applying any statistical test necessitates stating the null hypothesis. A null hypothesis is "a hypothesis of no difference" (Siegel,op.cit.:7). It is established in order to be rejected at the expense of an alternative hypothesis (H<sub>a</sub>) which is "the operational statement of the experimenter's research hypothesis" (Siegel,ibid). In this connection, Runyon and Haber (op.cit.:222) mention that the null hypothesis and its opposite, viz. the alternative hypothesis, are 'mutually exclusive and exhaustive' statistical hypotheses. That is to say, when the null hypothesis is falsified, the alternative hypothesis is validated and vice versa. As a result the following null hypotheses have been assumed:

- $\star$  H<sub>01.</sub> The duration of a geminate consonant is shorter than that of its single partner when occurring within the same phonetic context.
- $\bullet$  H<sub>02.</sub> The preceding vowel /a/ duration is affected by the following consonant duration whether it is a single or geminate consonant.
- ❖ H<sub>03.</sub> The vowel /a/ lengthens after a geminate consonant, but it shortens after its non-geminate counterpart.

Furthermore, the significance level at which the null hypotheses can be rejected has been specified. There are common values of probability, such as 0.01 and 0.05, the use of which is restricted by the context (Siegel,op.cit.:8; Lindsay,op.cit.:76). In the present study, two levels of significance have been determined: the first level where there is a considerably significant difference between the groups means, the p-value equals or less than 0.01 ( $p \le 0.01$ ); the second level where the difference is merely significant, the p-value equals or less than 0.05 ( $p \le 0.05$ ). Consequently, the differences are considered as nonsignificant where the p-value is more than 0.05 (p > 0.05).

However, while testing the null hypotheses, two types of error might arise: first, type I error which implies rejecting the null hypothesis when it is true; second, type II error which indicates acceptance of the null hypothesis when it is false (Siegel,op.cit.:9; Runyon and Haber,op.cit.:220). In order to avoid committing type I error, the probability has been chosen to be as low as possible (0.01), i.e. the researcher risks a type I error about one time in every hundred. Yet, such a level of significance may increase making a type II error; therefore, it has been chosen to be (0.05). Runyon and Haber (ibid:220-21) state that:

...the lower we set the rejection level, the less is the likelihood of a type I error, and the greater is the likelihood of a type II error. Conversely, the higher we set the rejection level, the greater the likelihood of a type I error and the smaller the likelihood of a type II error.

Following this, another parametric statistical test was applied, viz. the one-way ANOVA. It allows comparing the means of more than two groups (Ingram, 1977:262). Runyon and Haber (op.cit.:288) consider the ANOVA as "a technique of statistical analysis which permits us to overcome the ambiguity

involved in assessing significant differences when more than one comparison is made." More specifically, it allows comparing one variable with other variables for determining the differences. After applying the ANOVA, two additional null hypotheses have to be stated; they are as follows:

- ❖ H<sub>04</sub> The preceding vowel /a/ duration tends to shorten when occurring before a geminate consonant followed by a short vowel; whereas it tends to lengthen before a geminate consonant followed by a long vowel.
- ❖ H<sub>05</sub> The following vowel /a/ duration shows a tendency to shorten when occurring after a single consonant preceded by a short vowel; while it tends to lengthen after a single consonant preceded by a long vowel.

The same levels of significance have been also adopted for the ANOVA.

## 5.3 Results

After completing the segmentation procedure, the measurements were reported and the statistical tests results which clarify the statistically significant differences were stated. The tables were designed in such a way that the average values and standard deviations in addition to t- and f- values which help obtain the p-value for the purpose of determining the degree of significance of the differences between the groups means were displayed. The results are presented in detail as follows:

## 5.3.1 The Mean Durations of Voiceless and Voiced Single Versus Geminate

# **Consonants**

Generally, the findings of this experiment indicated that there was a considerable difference between single and geminate consonant durations. It was found that single consonants were significantly shorter than their geminate partners regardless of their being voiceless or voiced. It was also observed that a geminate consonant was nearly more than twice the length of its single counterpart.

Moreover, it was noticed that the durations of voiceless consonants, whether they were singles or geminates, were relatively longer than those of the voiced ones.

The results showed that the mean durations of the single voiceless dentialveolar and velar plosives /t/ and /k/ pronounced in the words /'fataħ/ and /'ðakar/ when produced in isolation were 9.05 csec. and 11.25 csec., respectively. And when the same words were spoken within a carrier sentence, their mean durations were 7.9 csec. and 9.75 csec., respectively. In fact, the durations of /t/ and /k/, whether they were produced in isolation or in a carrier sentence, were found to be shorter than those of their geminate counterparts /tt/ and /kk/ when occurring in similar phonetic environments. Thus, the mean durations of /tt/ and /kk/ pronounced in the words /'fattaħ/ and /'ðakkar/ when said in isolation were 22.25 csec. and 24.45 csec., respectively. The mean durations of /tt/ and /kk/ in the words under investigation which were enunciated in a carrier sentence were 19.2 csec. and 20.65 csec., respectively. In the same way, the voiceless labio-dental and palato-alveolar fricatives /f/ versus /ff/ and /ʃ/ versus /ʃʃ/ revealed a similar tendency, i.e. they showed very significant durational contrasts. The measurements displayed that the mean durations of the singles /f/ and /J/ employed in the words /'nafað/ and /'haʃad/ when spoken in isolation were 10.7 csec. and 11.75 csec. And when the words were pronounced in a carrier sentence, their mean durations were 8.95 csec. and 10.5 csec., respectively. On the other hand, the mean durations of their geminate counterparts /ff/ in /'naffað/ and /ff/ in /'haffad/ when uttered in isolation were 23.55 csec. and 23.4 csec. And their mean durations were 19.05 csec. and 19.1 csec. when the words were said within a phonetic context. See tables (5.1) and (5.2).

Regarding the voiced consonants, durational differences were also so clear where the single voiced consonants were, generally, shorter than their geminate partners. As a result, the mean durations of the single voiced denti-alveolar /d/ in

the word /ˈhadaθ/ when enunciated in isolation and in a carrier sentence were 7.05 csec. and 6 csec., respectively; whereas the mean durations of its geminate cognate /dd/ in /ˈhaddaθ/ when spoken both in isolation and in a carrier sentence were 20.9 csec. and 17.5 csec. Similarly, the interdental and denti-alveolar fricatives /ð/ and /z/ occurring in the words /ˈnaðam/ and /ˈχazan/ had the mean durations 6.65 csec. and 8.65 csec. when the words were produced in isolation, and when the words in question were uttered within context, their mean durations were 5.85 csec. and 7.75csec. Yet, the durations of the geminates /ðð/ in /ˈnaððam/ and /zz/ in /ˈγazzan/ were longer than those of their single partners where their mean durations were found to be 18.7 csec. and 19.85 csec., respectively, when the words were enunciated in isolation. And their mean durations were 16.85 csec. and 16.95 csec. when the words were said within a phonetic context.

The single palato-alveolar affricate /dʒ/ was highly significantly shorter than its doubled partner /dʒdʒ/. The results showed that the mean durations of /dʒ/ in /'radʒaʕ/ when produced both in isolation and within a carrier sentence were 9.25 csec. and 8.45 csec.; whereas the mean durations of its geminate counterpart /dʒdʒ/ in /'radʒdʒaʕ/ when spoken both in isolation and in a carrier sentence were 21.15 csec. and 17.85 csec. The results also exposed a noticeable durational contrast between the single bilabial nasal /m/ and its doubled cognate /mm/. The mean durations of /m/ used in /'hamal/ when produced in isolation and in a carrier sentence were 8.05 csec. and 7.1 csec., respectively. However, the mean durations of /mm/ pronounced in /'hammal/ when uttered in isolation and within a phonetic context were 20.85 csec. and 19.1 csec., respectively. See tables (5.3) and (5.4).

Furthermore, the findings indicated that the voiceless consonants had longer durations than those of the voiced ones regardless of their being non-geminates or

geminates. More importantly, it was observed that the duration of a geminate consonant was relatively more than twice the length of its non-geminate cognate. Based on the measurements, it can be easily recognized that the segmental mean durations of the consonantal types under inspection tended to be relatively longer when pronounced in words spoken in isolation than those said within a carrier sentence. The t-test results in the tables above indicated that there were highly significant durational differences between non-geminate and geminate consonants whether they were uttered in isolation or in a carrier sentence where the p-value is less than 0.01 (p<0.01). Consequently, the null hypothesis (H<sub>01</sub>) can be rejected.

#### 5.3.2 The Mean Durations of Vowel /a/ Before Voiceless and Voiced

#### Single Versus Geminate Consonants

After completing the segmentation procedure, the measurements obtained pointed out that the duration of the preceding vowel /a/ exposed insignificant durational variation when it occurred before voiceless and voiced single versus geminate consonants even though vowel /a/ duration still had a very short duration as compared to that of the following geminate consonant regardless of its being voiceless or voiced. As a result, the mean durations of vowel /a/ before the voiceless denti-alveoar and velar plosives /t/ in /'fatah/ and /k/ in /'ðakar/ when produced in isolation were 8.45 csec. and 8.9 csec., respectively. And when these words were said in a carrier sentence, its mean durations were 7.85 csec. and 8.05 csec.; while the mean durations of /a/-sound before /tt/ in /'fattah/ and /kk/ in /'ðakkar/ when enunciated in isolation were 8.15 csec. and 8.9 csec. And when the words were spoken in a carrier sentence, its mean durations were 7.75 csec. and 8.1 csec. Likewise, the vowel /a/ insignificantly varied its duration before the voiceless labio-dental and palato-alveolar fricatives /f/ versus /ff/ and /ʃ/ versus /ff/. As a consequence, the mean durations of the vowel /a/ before /f/ in /'nafað/

and /ʃ in /ˈħaʃad/ when uttered in isolation were 9.3 csec. and 8.25 csec., and its mean durations, as the words were produced within context, were 8.35 csec. and 8.1 csec. Occurring before the geminate fricatives /ff/ and /ʃʃ/, the vowel /a/ duration showed negligible durational variation in comparison to its duration before their single partners. Thus, the mean durations of vowel /a/ before /ff/ in /ˈnaffað/ and /ʃʃ/ in /ˈħaʃʃad/ when spoken in isolation were 9.45 csec. and 8.05 csec. And when the words were read in context, its mean durations were 8.85 csec. and 8 csec. See tables (5.5) and (5.6).

The vowel /a/ duration exposed a similar tendency when occurring before the single voiced denti-alveolar plosive /d/ in /'hadaθ/ where its mean durations were 8.9 csec. and 8.15 csec., as the word in question was read in isolation and, then, within a phonetic context. Its mean durations before /dd/ in /'haddaθ/ when uttered in isolation and in a carrier sentence were 8.6 csec. and 8.45 csec. Similarly, the results displayed that the mean durations of vowel /a/ preceding the voiced interdental and denti-alveolar fricatives /ð/ in /'nað/am/ and /z/ in /χazan/ when said in isolation were 10.75 csec. and 11.1 csec. And when the words were spoken within a phonetic context, its mean durations were 9.85 csec. and 9.7 csec. The vowel /a/ still showed negligible durational variation as it occurred before the geminate fricatives /ð/ð/ in /'nað/ð/am/ and /zz/ in /'χazzan/. Consequently, the mean durations of the preceding vowel /a/ when the words in question were read in isolation were found to be 10.8 csec. and 10.85 csec. When the words were produced within a phonetic context, the mean durations of /a/-sound were 10 csec. and 10.45 csec.

In the same way, before the palato-alveolar affricate /dʒ/ versus /dʒdʒ/, the vowel /a/ exhibited nonsignificant durational change. Therefore, its mean durations before /dʒ/ in /ˈradʒaʕ/ when uttered in isolation and in a context were 10.95 csec.

and 10.9 csec. The mean durations of the vowel /a/ before /dʒdʒ/ in /ˈradʒdʒaʕ/ when the word was enunciated in isolation and in a carrier sentence were 11 csec. and 10.4 csec. The results also exposed that vowel /a/ duration yielded negligible durational change when it occurred before the bilabial nasal /m/ versus /mm/. Thus, the mean durations of vowel /a/ before /m/ in /ˈħamal/ when the word was produced in isolation and in a carrier sentence were 8.75 csec. and 8.25 csec. And its mean durations before /mm/ in /ˈħammal/ when spoken in isolation and within a phonetic environment were 8.2 csec. and 7.8 csec., respectively. Thus, the null hypothesis H<sub>02</sub> can be rejected at p>0.05. See tables (5.7) and (5.8).

Nevertheless, it was observed that the vowel /a/ exposed negligible durational difference in accordance with the voicing feature of the following consonant. Consequently, it tended to be very slightly; yet, insignificantly, longer before a voiced consonant than before a voiceless one. For instance, the mean durations before the voiceless fricatives /f/ in /'nafað/ and the voiced fricative /ð/ in /'naðam/ when said in isolation were 9.3 csec. and 10.75 csec. And its mean durations, as the words were spoken in a carrier sentence, were 8.35 csec. and 9.85 csec. By the same token, the mean durations of vowel /a/ before /ff/ in /'naðfað/ and /ðð/ in /'naððam/ when said in isolation were 9.45 csec. and 10.8 csec.; besides, its mean durations when the words in question were pronounced in a carrier sentence were 8.85 csec. and 10 csec., respectively. The measurements mentioned above revealed that the vowel before a voiced consonant was very slightly longer, though insignificantly, than that before a voiceless one.

## 5.3.3 The Mean Durations of Vowel /a/ After Voiceless and Voiced

# Single Versus Geminate Consonants

The results indicated that the duration of the post consonantal vowel (following vowel)/a/showed a different tendency from that of the pre-consonantal

vowel (preceding vowel). It was recognized that the vowel /a/ tended to lengthen after non-geminate consonants; whereas it shortened after their geminate partners whether they were voiceless or voiced. The mean durations of vowel /a/ after the single voiceless denti-alveolar and velar plosives /t/ in /'fataħ/ and /k/ in /'ðakar/ when spoken in isolation were 10.55 csec. and 13.75 csec., and when the words were produced in a carrier sentence, its mean durations were 9.25 csec. and 12.4 csec. However, it tended to shorten after their geminate counterparts where its mean durations after /tt/ in /'fattaħ/ and /kk/ in /'ðakkar/ when said in isolation were 8.2 csec. and 11.1, and its mean durations, as the words were produced in a phonetic context, were 7.7 csec. and 8.95 csec., respectively. The duration of the vowel /a/ exhibited an obvious tendency to lengthen after the single voiceless labio-dental and palato-alveolar fricatives /f/ and /ʃ/. Thus, the mean durations of /a/-sound after /f/ in /'nafað/ and /ʃ/ in /'haʃad/ when uttered in isolation were 13.55 csec. and 12.25 csec. And when the words were enunciated in a carrier sentence, its mean durations were 11.85 csec. and 10.65 csec. Yet, the mean durations of vowel /a/ after /ff/ in /'naffað/ and /ff/ in /'haffad/ when spoken in isolation were 9.65 csec. and 10.15 csec. And when the words were said within a phonetic environment, its mean durations were 9.2 csec. and 8.4 csec. See tables (5.9) and (5.10).

In the same way, the duration of the vowel /a/ showed highly significant differences after voiced single versus geminate consonants. The acoustic measurements displayed that the mean durations of vowel /a/ after the single dentialveolar plosive /d/ used in /ˈħadaθ/ versus /dd/ in /ˈħaddaθ/ when pronounced in isolation were 12.3 csec. and 8.95 csec. Still, the durational differences were so evident when the words were read in a carrier sentence where the mean durations of vowel /a/ after /d/ versus /dd/ were found to be 11.65 cse. and 8.25 csec., respectively. Similarly, vowel /a/ tended to lengthen after the single interdental and

denti-alveolar fricatives /ð/ and /z/ rather than after their geminate counterparts /ðð/ and /zz/. Therefore, the mean durations of /a/-sound after /ð/ in /'naðam/ and /z/ in /'xazan/ when uttered in isolation were 12.35 csec. and 13 csec. Conversely, the mean durations of vowel /a/ after /ðð/ in /'naððam/ and /zz/ in /'xazzan/ when read in isolation were 9 csec. and 10.1 csec. More to the point, the durational differences were quite obvious when the words were enunciated within a phonetic context. As a result, the mean values of /a/-sound after /ð/ and /z/ in the words examined, when spoken in a carrier sentence, were 11.9 csec. and 11.65 csec.; while its mean durations after /ðð/ and /zz/ were 8.05 csec. and 8.75 csec., respectively. There were also very significant durational differences, on the part of the following vowel /a/, as it occurred after the palato-alveolar affricate /dʒ/ versus /dʒdʒ/ and the bilabial nasal /m/ versus /mm/. As a consequence, the mean durations of vowel /a/ after /dʒ/ in /'radʒas/ versus /dʒdʒ/ in /'radʒdʒas/ when produced in isolation were 10.95 csec. and 8.2 csec. The difference was still clearcut when the words were read within a phonetic context where its mean durations after /dʒ/ versus /dʒdʒ/ when the words were spoken in a carrier sentence were 10.05 csec. and 7.8 csec. Similarly, the duration of vowel /a/ tended to lengthen after single /m/ rather than after its geminate partner /mm/. As a result, the mean durations of /a/-sound after /m/ in /hamal/ versus /mm/ in /hammal/ when uttered in isolation were 12.35 csec. and 8.8 csec. And when the words were spoken within a phonetic context, the mean durations of vowel /a/ after /m/ versus /mm/ were 10.35 csec. and 7.9 csec. See tables (5.11) and (5.12). Consequently, the null hypothesis  $H_{03}$  can be rejected at p $\leq 0.05$ .

Additionally, the length of the following vowel negatively affected the duration of the preceding single consonant, i.e. the lengthening of the following vowel is compensated for by shortening the preceding single consonant. But, in the

event of geminate consonants, the shortening of the following vowel was compensated for by the long duration of the preceding geminate consonant. Consequently, the results showed that the durations of prevocalic voiceless single plosive /k/ and the following vowel /a/ were significantly different at p<0.05 whether they occurred in isolation or within a carrier sentence. It was found that the mean durations of /k/ and the following /a/ in /'ðakar/ when pronounced in isolation were 11.25 csec. and 13.75, and their mean durations, as the word was produced in a carrier sentence, were 9.75 csec. and 12.4 csec., respectively.

However, this was not really the case in the event of the voiceless dentialveolar plosive /t/. In other words, the measurements showed that there was statistically insignificant durational difference between the prevocalic plosive /t/ and the following vowel /a/ at p>0.05 whether they were uttered within isolated words or said in words spoken in a carrier sentence. Therefore, the mean durations of /t/ and the following vowel /a/ in /'fataħ/ when said in isolation were 9.05 csec. and 10.55 csec. And when the word was read in a carrier sentence, their mean durations were 7.9 csec. and 9.25 csec. Still, the negative effect of the voiceless geminate consonant duration on the duration of the following vowel /a/ was statistically very significant in the case of both /tt/ and /kk/ whether they were enunciated in isolation or in a carrier sentence where the p-value was less than 0.01 (p<0.01). The measurements showed that the mean durations of the preceding /tt/ and the following vowel /a/ pronounced in /'fattaħ/ when uttered in isolation were 22.25 csec. and 8.2 csec., respectively, and it was found that their mean durations were 19.2 csec. and 7.7 csec. when the same word was said within a phonetic context. Besides, the mean durations of the preceding /kk/ and the following /a/-sound pronounced in /'ðakkar/ when said in isolation were 24.45 csec. and 11.1 csec. And when the word was read in a carrier sentence, their mean durations were found to be 20.65 csec. and 8.95 csec.

Similarly, the single labio-dental fricative /f/ tended to significantly shorten to compensate for the lengthening of the following vowel where the p<0.05. Thus, the mean durations of the prevocalic /f/ and the following /a/-sound in /'nafað/ when uttered in isolation were 10.7 csec. and 13.55 csec. And when the word was said within a phonetic context, their mean durations were 8.95 csec. and 11.85 csec. The compensatory effort was also noticed between the prevocalic /ff/ and the following /a/. The results exposed that the mean durations of the preceding /ff/ and the following /a/ pronounced in /'naffað/ when spoken in isolation were 23.55 csec. and 9.65 csec. And when the word was produced within a phonetic environment, their mean durations were 19.05 csec. and 9.2 csec. The duration of the single palato-alveolar fricative /ʃ/; however, exhibited insignificant durational variation as compared to the duration of the following vowel when produced in isolation and carrier sentence where the p-value was more than 0.05 (p>0.05). in Therefore, the mean durations of /ʃ/ and the following /a/ in /hasad/ when enunciated in isolation were 11.75 csec. and 12.25 csec., respectively. And when the word in question was said within a phonetic context, their mean durations were 10.5 csec. and 10.65 csec., respectively. Yet, there was an obvious negative effect of geminate /ff/ on the following vowel, i.e. it tended to very significantly shorten after a geminate consonant in order to compensate for the long duration of the preceding geminate consonant where the p-value was less than 0.01 (p<0.01). The results displayed that the mean durations of /ff/ and the following vowel /a/ in /haffad/ when said in isolation were 23.4 csec. and 10.15 csec.; besides, when the word was pronounced in a carrier sentence, their mean durations were 19.1 csec. and 8.4 csec., respectively. See tables (5.13-5.16).

The single denti-alveolar plosive /d/ revealed a striking compensatory effort in relation to the following vowel /a/ duration, i.e. in statistical terms there was a considerably significant durational difference between them where p<0.01. It was

observed that the prevocalic /d/ considerably shortened to compensate for the lengthening of the following vowel. Based on the measurements, the mean durations of /d/ and the following vowel /a/ in /hadaθ/ when spoken in isolation were 7.05 csec. and 12.3 csec.; besides, when the word was produced within context, their mean durations were 6 csec. and 11.65 csec. On the other hand, the following vowel tended to shorten in order to compensate for the long duration of the preceding geminate consonant /dd/. As a result, the mean durations of /dd/ and the following vowel /a/ in /haddaθ/ when uttered in isolation were 20.9 csec. and 8.95 csec. And when the word was enunciated within a phonetic context, their mean durations were 17.5 csec. and 8.25 csec., respectively. It was also observed that the durations of the single interdental and denti-alveolar fricatives /ð/ and /z/ very significantly shortened as a corollary of the lengthening of the following vowel where p<0.01. As a result, the mean durations of  $\frac{\delta}{a}$  and the following vowel /a/ in /'naðam/ when spoken in isolation were 6.65 csec. and 12.35 csec., and their mean durations, as the word was said within a phonetic context were 5.85 csec. and 11.9 csec. Likewise, the mean durations of /z/ and the following /a/sound in /'yazan/ when uttered in isolation were 8.65 csec. and 13 csec. And their mean durations, as the word was read within a carrier sentence, were 7.75 csec. and 11.65 csec. Contrary to that, the shortening of the following vowel was compensated for by the long duration of the preceding geminate consonant. Thus, the mean durations of /ðð/ and the following /a/-sound in /'naððam/ when enunciated in isolation were 18.7csec. and 9 csec.; besides, their mean durations, as the word was produced in a carrier sentence, were 16.85 csec. and 8.05 csec., respectively. In the same way, the mean durations of /zz/ and the following /a/sound in /'xazzan/ when uttered in isolation were 19.85 csec. and 10.1 csec. And when the word was read within a phonetic environment, their mean durations were 16.95 csec. and 8.75 csec., respectively.

Nevertheless, the single palato-alveolar affricate /dʒ/ showed a different tendency, i.e. it revealed insignificant durational difference in comparison to the duration of the following vowel at p>0.05. Yet, its geminate counterpart very significantly affected the following vowel duration at p<0.01. Based on the measurements, the mean durations of /dʒ/ and the following /a/ in /'radʒa\f\/ when spoken in isolation were 9.25 csec. and 10.95 csec. And their mean durations, as the word was said in a carrier sentence, were 8.45 csec. and 10.05 csec. On the other hand, the mean durations of /dzdz/ and the following /a/ in /'radzdzas/ when spoken in isolation were 21.15 csec. and 8.2 csec.; besides, when the word was enunciated in a carrier sentence, their mean durations were 17.85 csec. and 7.8 csec. The results, moreover, indicated that there were very significant differences between the bilabial nasal /m/ versus /mm/ and the following vowel duration occurring in words pronounced both in isolation and in a carrier sentence. It was found that the mean durations of /m/ and the following vowel /a/ in /hamal/ when produced in isolation were 8.05 csec. and 12.35 csec. And their mean durations, as the word was spoken within a phonetic context, were 7.1 csec. and 10.35 csec. The mean durations of /mm/ and the following /a/-sound in /hammal/ when uttered in isolation were 20.85 csec. and 8.8 csec. And when the word was read in a carrier sentence, their mean durations were 19.1 csec. and 7.9 csec. See tables (5.17-5.20).

More to the point, the following vowel duration showed insignificant durational variation in accordance with the voicing characteristic of the preceding consonant. To put it differently, vowel /a/ duration displayed negligible differences when it occurred after voiceless versus voiced consonants regardless of their being single or geminate consonants. For instance, the mean durations of /a/-sound after /t/ in /'fatah/ and /d/ in /'hadaθ/ when spoken in isolation were 10.55 csec. and 12.35 csec. And its mean durations, as the words were said in a carrier sentence, were 9.25 csec. and 10.35 csec. The vowel /a/ showed a similar tendency when

occurring after voiceless geminate /tt/ and its voiced counterpart /dd/. Consequently, the mean durations of /a/-sound after /tt/ in /'fattaħ/ and /dd/ in /'ħaddaθ/ when the words were uttered in isolation were 8.2 csec. and 8.95 csec. And its mean durations, when the words were pronounced within context, were 7.7 csec. and 8.25 csec., respectively.

#### 5.3.4 The Mean Durations of Vowel /a/ Before /-CCa-/-Sequences Versus

#### /-CCaa-/-Sequences

The findings of this experiment pointed out that there was a striking correlation between the duration of the preceding vowel /a/ and those of the postvocalic geminate consonant and the vowel by which it was followed whether it was the short vowel /a/ or the long vowel /aa/. More specifically, it was observed that the duration of the preceding vowel /a/ showed greatly significant durational differences when occurring before /-CCa-/-sequences versus /-CCaa-/-sequences at p<0.01.

The results disclosed that the mean durations of vowel /a/ before the geminate denti-alveolar plosive followed by a short vowel /-tta-/ in /'fattaħ/ when produced both in isolation and in a carrier sentence were 8.15 csec.and 7.75 csec.; whereas its mean durations before /-t'taa-/-sequence in /fat'taaħ/ when spoken in isolation and within a phonetic context were 6.45 csec. and 5.7 csec., respectively. Similarly, the vowel /a/ tended to be longer before the geminate emphatic denti-alveolar plosive /ţţ/ followed by a short vowel than that before the geminate emphatic plosive followed by a long vowel; therefore, the mean durations of vowel /a/ before /-ţţa-/-sequence in /'ʕaţţar/ when enunciated in isolation and within a phonetic environment were 9.3 csec. and 9.2 csec.; while its mean durations before /-ţ'ţaa-/-sequence in /ʕaţ'ţaar/ when uttered in isolation and within a phonetic context were 7.05 csec. and 6.7 csec. The results also displayed that the

mean durations of vowel /a/ before the voiceless pharyngeal fricative /ħħ/ followed by a short vowel in /'raħħal/ when spoken in isolation and in a carrier sentence were 9.7 csec. and 8.3 csec. Yet, its mean durations before /-ħ'ħaa-/-sequence in /raħ'ħaal/ when said in isolation and in a carrier sentence were 7.1 csec. and 6.55 csec. See tables (5.21-5.24).

By the same token, the measurements made for the vowel duration before voiced geminate consonants, whether they were preceded by a short or a long vowel, yielded considerably significant durational differences where the p-value was less than 0.01 (p<0.01). Thus, it was observed that the mean durations of /a/sound before the denti-alveolar fricative /zz/ followed by a short vowel occurring in /'χazzan/ when produced in isolation and in a carrier sentence were 10.85 csec. and 10.45 csec.; whereas its mean durations before /-z'zaa-/-sequence in /χaz'zaan/ when spoken in isolation and in a carrier sentence were 8.05 csec. and 7.95 csec., respectively. Further, it was found that the mean durations of vowel /a/ before the bilabial geminate nasal /mm/ followed by a short vowel in /'hammal/ when enunciated in isolation and in a carrier sentence were 8.2 csec. and 7.8 csec.; while its mean durations before /-m'maa-/-sequence in /ħam'maal/ when produced in isolation and in a carrier sentence were 6.6 csec. and 5.9 csec.

In addition, the results showed that the mean durations of the vowel /a/ occurring before the /-rra-/-sequence in /\sqrraf/ when uttered both in isolation and within a phonetic context were 10.3 csec. and 9.5 csec.; whereas its mean durations before /-r'raa-/-sequence in /\ssr'raaf / when said in isolation and in a carrier sentence were 7.35 csec. and 7 csec., respectively. Likewise, the vowel /a/ very significantly shortened before /ll/ followed by a long vowel rather than before /ll/ followed by a short vowel. As a consequence, the mean durations of vowel /a/ before /-lla-/-sequence in /\ssr'\sallam/ when read both in isolation and within a

phonetic environment were 9.1 csec. and 8.6 csec., respectively. However, the mean durations of /a/-sound before /-1'laa-/-sequence in /\subsetall'laam/ when said in isolation and, then, in a carrier sentence were 7.35 csec. and 6.55 csec., respectively. See tables (5.25-5.28). The results of the ANOVA test led to the rejection of the null hypothesis  $H_{04}$  at p\le 0.01, since the durational differences appeared to be considerably significant.

#### 5.3.5 The Mean Durations of Vowel /a/ After /-aC-/-Sequences Versus

#### /-aaC-/-Sequences

Once again, the results indicated that vowel /a/ revealed an inclination to be longer when occurring after voiceless or voiced single consonants which were preceded by the short vowel /a/ than after single consonants preceded by the long vowel /aa/. Statistically, there was a very significant durational difference between vowel durations preceded by /-aC-/-sequences in comparison to those preceded by /-aaC-/-sequences at p≤0.01. The results showed that the mean durations of vowel /a/ after a sequence consisting of the single uvular plosive /q/ preceded by a short vowel in /'naqaf/ when produced in isolation and within context were 13.15 csec. and 11.4 csec.; whereas it scored shorter duration as it was preceded by /-aaq-/-sequence in /'naaqaf/ when spoken in isolation and within a carrier sentence where its mean durations were found to be 10.55 csec. and 8.9 csec., respectively.

The vowel /a/ was also longer when occurring after the denti-alveolar fricative /s/ preceded by a short vowel than that after /s/ preceded by a long vowel. As a result, the mean durations of the vowel /a/ after /-as-/-sequence in /hasab/ when uttered in isolation and in a carrier sentence were 11.65 csec. and 10.15 csec.; while its mean durations after /-aas-/-sequence in /hasab/ when said in isolation and in a carrier sentence were 8.9 csec. and 7.8 csec. Similarly, the /a/sound showed a tendency to lengthen after the emphatic denti-alveolar fricative /s/

preceded by a short vowel rather than after /ṣ/ preceded by a long vowel. The measurements exposed that the mean durations of vowel /a/ after /-aṣ-/-sequence in /ˈwaṣal/ when spoken in isolation and in a carrier sentence were 12.7 csec. and 11.15 csec.; while its mean durations after /-aaṣ-/-sequence in /ˈwaaṣal/ when read in isolation and in a carrier sentence were 8.85 csec. and 7.65 csec., respectively. See tables (5.29-5.32).

In as far as the voiced consonants were concerned, the uvular fricative /ʁ/ preceded by a short vowel had a largely significant lengthening effect on the following vowel. Therefore, the mean durations of /a/-sound after /ʁ/ preceded by a short vowel in /ˈʃaʁal/ when uttered in isolation and in a carrier sentence were 12.7 csec. and 11.75 csec. However, it tended to shorten after /-aaʁ-/-sequence in /ˈʃaaʁal/ when said in isolation and within a phonetic context. As a result, the mean durations of vowel /a/ were 9.4 csec. and 8.35 csec., respectively. Finally, the results showed that the mean durations of /a/-sound after the palato-alveolar affricate /ʤ/ preceded by a short vowel pronounced in /ˈraɑʤaʕ/ when enunciated in isolation and in a carrier sentence were 11.95 csec. and 10.05 csec.; while its mean durations after /-aaʤ-/-sequence in /ˈraaʤaʕ/ when said in isolation and within a phonetic environment were 8.4 csec. and 7.65 csec., respectively. See tables (5.33-5.36) for more clarification. In statistical terms, the ANOVA results signified that the durational differences were substantially significant at p≤0.01. Hence, the null hypothesis (H₀s) can be refuted.

Table (5.1): The Mean Durations of Voiceless Single vs. Geminate Consonants

Pronounced in Words of the Patterns /'fa\al/~/'fa\al/

Produced in Isolation

Consonants	Mean Durations of Single Consonant		Mean Durations of Geminate Consonant		T-Value
/t/ vs. /tt/	9.05	S.D. 1.2	22.25	S.D. 2.9	12.79
/k/ vs. /kk/	11.25	S.D. 1.7	24.45	S.D. 5.1	7.74
/f/ vs. /ff/	10.7	S.D. 2.1	23.55	S.D. 3.9	8.73
/ʃ/ vs. /ʃʃ/	11.75	S.D. 1.9	23.4	S.D. 2.4	11.55
P-Value < 0.01					

Table (5.2): The Mean Durations of Voiceless Single vs. Geminate Consonants

Pronounced in Words of the Patterns /'fa\al/~/'fa\al/~/'fa\al/

Produced in Context

Consonants	Mean Durations of Single Consonant		Mean Durations of Geminate Consonant		T-Value	
/t/ vs. /tt/	7.9	S.D. 1.2	19.2	S.D. 1.9	9.16	
/k/ vs. /kk/	9.75	S.D. 1.4	20.65	S.D. 3	7.55	
/f/ vs. /ff/	8.95	S.D. 1.9	19.05	S.D. 2.7	9.51	
/ʃ/ vs. /ʃʃ/	10.5	S.D. 1.5	19.1	S.D. 2.3	9.30	
P-Value < 0.01						

Table (5.3): The Mean Durations of Voiced Single vs. Geminate Consonants Pronounced in Words of the Patterns /'fasal/~/'fassal/ Produced in Isolation

Consonants				n Durations of nate Consonant	T-Value		
/d/ vs. /dd/	7.05	S.D. 1.1	20.9	S.D. 5.1	8.02		
/ð/ vs. /ðð/	6.65	S.D. 0.9	18.7	S.D. 3.1	11.31		
/z/ vs. /zz/	8.65	S.D. 1.4	19.85	S.D. 2.9	10.54		
/dʒ/ vs. /dʒdʒ/	9.25	S.D. 1.2	21.15	S.D. 4.0	8.64		
/m/ vs. /mm/	8.05	S.D. 0.7	20.85	S.D. 4.2	9.06		
	P-Value<0.01						

Table (5.4): The Mean Durations of Voiced Single vs. Geminate Consonants Pronounced in Words of the Patterns /'fasal/~/'fassal/ Produced in Context

Consonants	Mean Durations of Single Consonant			n Durations of nate Consonant	T-Value	
/d/ vs. /dd/	6	S.D. 1.1	17.5	S.D. 3.3	10.04	
/ð/ vs. /ðð/	5.85	S.D. 0.8	16.85	S.D. 3.1	10.59	
/z/ vs. /zz/	7.75	S.D. 1.5	16.95	S.D. 3.0	8.33	
/dʒ/ vs. /dʒdʒ/	8.45	S.D. 0.8	17.85	S.D. 3.4	8.17	
/m/ vs. /mm/	7.1	S.D. 1.2	19.1	S.D. 3.6	9.41	
P-Value<0.01						

Table (5.5): The Mean Durations of Vowel /a/ BeforeVoiceless Single vs. Geminate

Consonants Pronounced in Words of the Patterns /'fa\al/~

Consonants	Mean Durations of /a/ Before a Single		Mean Durations of /a/ Before a Geminate		T-Value	
/t/ vs. /tt/	8.45	S.D. 2.1	8.15	S.D. 1.6	0.35	
/k/ vs. /kk/	8.9	S.D. 2.2	8.9	S.D. 1.9	0.00	
/f/ vs. /ff/	9.3	S.D. 2.7	9.45	S.D. 1.8	0.14	
/ʃ/ vs. /ʃʃ/	8.25	S.D. 3.2	8.05	S.D. 2.07	0.16	
	P-Value NS					

Table (5.6): The Mean Durations of Vowel /a/ BeforeVoiceless Single vs. Geminate

Consonants Pronounced in Words of the Patterns /'fa\al/~/'fa\al/~/'fa\al/~/'fa\al/~/'fa\al/~/'fa\al/~/'fa\al/~/'fa\al/~/'fa\al/~/'fa\al/~/

Consonants	Mean Durations of /a/ Before a Single		Mean Durations of /a/ Before a Geminate		T-Value	
/t/ vs. /tt/	7.85	S.D. 1.3	7.75	S.D.1.006	0.18	
/k/ vs. /kk/	8.05	S.D. 1.4	8.1	S.D. 0.7	0.10	
/f/ vs. /ff/	8.35	S.D. 1.001	8.85	S.D. 1.2	0.97	
/ʃ/ vs. /ʃʃ/	8.1	S.D. 1.2	8	S.D. 0.7	0.22	
P-Value NS						

Table(5.7): The Mean Durations of Vowel /a/ Before Voiced Single vs. Geminate Consonants Pronounced in Words of the Patterns /'fasal/~/'fassal/ Produced in Isolation

Consonants	Mean Durations of /a/ Before a Single		Mean Durations of /a/ Before a Geminate		T-Value		
/d/ vs. /dd/	8.9	S.D. 2.2	8.6	S.D. 2.06	0.31		
/ð/ vs. /ðð/	10.75	S.D. 2.5	10.8	S.D. 2.3	0.05		
/z/ vs. /zz/	11.1	S.D. 3.1	10.85	S.D. 2.6	0.19		
/dʒ/ vs. /dʒdʒ/	10.95	S.D. 2.7	11	S.D. 2.3	0.04		
/m/ vs. /mm/	8.75	S.D. 2.03	8.2	S.D. 1.3	0.71		
	P-Value NS						

Table(5.8): The Mean Durations of Vowel /a/ Before Voiced Single vs. Geminate Consonants Pronounced in Words of the Patterns /'fa\alpha|/~/'fa\alpha\alpha|/ Produced in Context

Consonants	Mean Durations of /a/ Before a Single		Mean Durations of /a/ Before a Geminate		T-Value	
/d/ vs. /dd/	8.15	S.D. 1.9	8.45	S.D. 2.03	0.34	
/ð/ vs. /ðð/	9.85	S.D. 2.02	10	S.D. 1.3	0.20	
/z/ vs. /zz/	9.7	S.D. 1.8	10.45	S.D. 1.6	0.96	
/dʒ/ vs. /dʒdʒ/	10.9	S.D. 2.01	10.4	S.D. 1.5	0.62	
/m/ vs. /mm/	8.25	S.D. 1.5	7.8	S.D. 2.09	0.55	
P-Value NS						

Table(5.9): The Mean Durations of Vowel /a/ After Voiceless Single vs. Geminate

Consonants Pronounced in Words of the Patterns /'fa\al/~/'fa\al/\

Produced in Isolation

Consonants	Mean Durations of /a/ After a Single		Mean Durations of /a/ After a Geminate		T-Value	
/t/ vs. /tt/	10.55	S.D. 2.8	8.2	S.D. 1.7	2.24	
/k/ vs. /kk/	13.75	S.D. 3.06	11.1	S.D. 1.7	2.37	
/f/ vs. /ff/	13.55	S.D. 2.9	9.65	S.D. 1.2	3.91	
/ʃ/ vs. /ʃʃ/	12.25	S.D. 2.3	10.15	S.D. 1.8	2.17	
<b>P-Value ≤0.05</b>						

Table(5.10): The Mean Durations of Vowel /a/ After Voiceless Single vs. Geminate

Consonants Pronounced in Words of the Patterns /'fa\al/~/'fa\al/

Produced in Context

Consonants	Mean Durations of /a/ After a Single		Mean Durations of /a/ After a Geminate		T-Value	
/t/ vs. /tt/	9.25	S.D. 2.03	7.7	S.D. 1.1	2.06	
/k/ vs. /kk/	12.4	S.D. 2.8	8.95	S.D. 1.2	3.81	
/f/ vs. /ff/	11.85	S.D. 2.6	9.2	S.D. 0.7	3.03	
/ʃ/ vs. /ʃʃ/	10.65	S.D. 2.4	8.4	S.D. 1.1	2.67	
P-Value<0.01						

Table(5.11.): The Mean Durations of Vowel /a/ After Voiced Single vs. Geminate

Consonants Pronounced in Words of the Patterns /'fasal/~/'fassal/ Produced in Isolation

Consonants	Mean Durations of /a/ After a Single		Mean Durations of /a/ After a Geminate		T-Value	
/d/ vs. /dd/	12.3	S.D. 2.8	8.95	S.D. 1.3	3.34	
/ð/ vs. /ðð/	12.35	S.D. 3.1	9	S.D. 1.4	3.05	
/z/ vs. /zz/	13	S.D. 2.8	10.1	S.D. 2.2	2.51	
/dʒ/ vs. /dʒdʒ/	10.95	S.D. 2.4	8.2	S.D. 0.7	3.17	
/m/ vs. /mm/	12.35	S.D. 3.8	8.8	S.D. 0.4	2.89	
P-Value<0.01						

Table(5.12): The Mean Durations of Vowel /a/ After Voiced Single vs. Geminate

Consonants Pronounced in Words of the Patterns /'fasal/~/'fasal/ Produced in Context

Consonants	Mean Durations of /a/ After a Single		Mean Durations of /a/ After a Geminate		T-Value	
/d/ vs. /dd/	11.65	S.D. 2.3	8.25	S.D. 0.4	4.55	
/ð/ vs. /ðð/	11.9	S.D. 2.7	8.05	S.D. 0.4	4.35	
/z/ vs. /zz/	11.65	S.D. 3.1	8.75	S.D. 2.3	2.34	
/dʒ/ vs. /dʒdʒ/	10.05	S.D. 2.9	7.8	S.D. 1.1	2.23	
/m/ vs. /mm/	10.35	S.D. 2.5	7.9	S.D. 1.02	2.78	
P-Value<0.01						

Table(5.13): The Mean Durations of the Preceding Voiceless Single Consonants and the Following vowel /a/ Pronounced in Words of the Pattern /'fa\all/
Produced in Isolation

Consonants	Mean Durations of a Preceding Single		Mean Durations of a Following/a/		T-Value
/t/	9.05	S.D. 1.2	10.55	S.D. 2.8	1.55
/k/	11.25	S.D. 1.6	13.75	S.D. 3.06	2.25
/ <b>f</b> /	10.7	S.D. 2.13	13.55	S.D. 2.9	2.44
/ʃ/	11.75	S.D. 1.8	12.25	S.D. 2.3	0.50
P-Value <0.05					

Table(5.14): The Mean Durations of the Preceding Voiceless Single Consonants and the Following vowel /a/ Pronounced in Words of the Pattern /ˈfaʕal/

Produced in Context

Consonants	Mean Durations of a Preceding Single		Mean Durations of a Following/a/		T-Value	
/t/	7.9	S.D. 1.2	9.25	S.D. 2.03	1.76	
/k/	9.75	S.D. 1.4	12.4	S.D. 2.8	2.63	
/ <b>f</b> /	8.95	S.D. 1.8	11.85	S.D. 2.6	2.76	
/ʃ/	10.5	S.D. 1.4	10.65	S.D. 2.4	0.16	
	P-Value < 0.05					

Table(5.15): The Mean Durations of the Preceding Voiceless Geminate Consonants and the Following vowel /a/ Pronounced in Words of the Pattern /'fassal/
Produced in Isolation

Consonants	Mean Durations of a Preceding geminate		Mean Durations of a Following/a/		T-Value
/tt/	22.25	S.D. 3.02	8.2	S.D. 1.7	12.70
/kk/	24.45	S.D. 4.8	11.1	S.D. 1.7	7.81
/ <b>ff</b> /	23.55	S.D. 3.8	9.65	S.D. 1.2	10.35
/[[/	23.4	S.D. 2.3	10.15	S.D. 1.8	13.52
P-Value<0.01					

Table(5.16): The Mean Durations of the Preceding Voiceless Geminate Consonants and the Following vowel /a/ Pronounced in Words of the Pattern /'fassal/
Produced in Context

Consonants	Mean Durations of a Preceding geminate		Mean Durations of a Following/a/		T-Value	
/tt/	19.2	S.D. 3.6	7.7	S.D. 0.4	9.40	
/kk/	20.65	S.D. 4.1	8.95	S.D. 0.4	8.52	
/ <b>ff</b> /	19.05	S.D. 2.5	9.2	S.D. 2.3	11.10	
/ʃʃ/	19.1	S.D. 1.4	8.4	S.D. 1.1	12.51	
	P-Value<0.01					

Table(5.17): The Mean Durations of the Preceding Voiced Single Consonants and the Following vowel /a/ Pronounced in Words of the Pattern /ˈfaʕal/ Produced in Isolation

Consonants	Mean Durations of a Preceding Single		Mean Durations of a Following/a/		T-Value	
/ <b>d</b> /	7.05	S.D. 1.2	12.3	S.D. 2.8	5.36	
/ð/	6.65	S.D. 0.8	12.35	S.D. 3.1	5.52	
/z/	8.65	S.D. 1.3	13	S.D. 2.8	4.33	
/dʒ/	9.25	S.D. 1.1	10.95	S.D. 2.4	1.85	
/ <b>m</b> /	8.05	S.D. 1.1	12.35	S.D. 3.8	3.45	
	P-Value<0.01					

Table(5.18): The Mean Durations of the Preceding Voiced Single Consonants and the Following vowel /a/ Pronounced in Words of the Pattern /ˈfaʕal/ Produced in Context

Consonants	Mean Durations of a Preceding Single		Mean Durations of a Following/a/		T-Value
/ <b>d</b> /	6	S.D. 1.09	11.65	S.D. 2.3	6.92
/ð/	5.85	S.D. 0.7	11.9	S.D. 2.7	6.65
/z/	7.75	S.D. 1.5	11.65	S.D. 3.1	3.49
/dʒ/	8.45	S.D. 0.78	10.05	S.D. 2.9	1.64
/m/	7.1	S.D. 1.1	10.35	S.D. 2.5	3.59
P-Value<0.01					

Table(5.19): The Mean Durations of the Preceding Voiced Geminate Consonants and the Following vowel /a/ Pronounced in Words of the Pattern /'fassal/ Produced in Isolation

Consonants		ourations of a		Mean Durations of a Following/a/					
/dd/	20.9	S.D. 5.06	8.95	S.D. 1.3	6.87				
/ðð/	18.7	S.D. 3.07	9	S.D. 1.4	8.60				
/zz/	19.85	S.D. 2.8	10.1	S.D. 2.2	2.51				
/क्रुक्र/	21.15	S.D. 3.9	8.2	S.D. 0.7	3.17				
/mm/	20.85	S.D. 4.1	8.8	S.D. 0.4	8.61				
P-Value<0.01									

Table(5.20): The Mean Durations of the Preceding Voiced Geminate Consonants and the Following vowel /a/ Pronounced in Words of the Pattern /ˈfassal/ Produced in Context

Consonants		rations of a g geminate		ırations of a owing/a/	T-Value				
/dd/	17.5	17.5 S.D. 3.2		S.D. 0.4	8.44				
/ðð/	16.85	S.D. 3.01	8.05	S.D. 0.4	8.65				
/zz/	16.95	S.D. 2.9	8.75	S.D. 2.3	6.67				
/वेउवेऽ/	17.85	S.D. 3.36	7.8	S.D. 1.1	8.52				
/mm/	19.1	S.D. 3.6	7.9	S.D. 1.02	8.91				
P-Value<0.01									

Table(5.21): The Mean Durations of the Preceding Vowel /a/ and the Following Voiceless Geminate Consonants /CC/ Followed by a Short Vowel

#### Pronounced in Words of the Pattern /'fassal/

#### **Produced in Isolation**

Sequence		/a/	/	/CC/		/a/	F-Value				
/-tta-/	8.15	S.D. 1.5	22.25	S.D. 3.02	8.2	S.D. 1.9	131.82				
/-ţţa-/	9.3	S.D. 2.1	23	S.D. 4	11.2	S.D. 1.1	51.47				
/ <b>-ħħa</b> -/	9.7	S.D. 1.08	23.75	S.D. 4.3	11	S.D. 2.5	68.89				
	P-Value≤0.01										

Table(5.22): The Mean Durations of the Preceding Vowel /a/ and the Following Voiceless Geminate Consonants /CC/ Followed by a Short Vowel

#### Pronounced in Words of the Pattern /'fassal/

Sequence	/a/		/(	/CC/		/a/	
/-tta-/	7.75	S.D. 1.5	19.2	S.D. 6	7.7	S.D. 1.9	82.398
/-ţţa-/	9.2	S.D. 0.8	19.75	S.D. 3.6	11.85	S.D. 2.7	46.45
/ <b>-</b> ħħa-/	8.3	S.D. 1.3	21.25	S.D. 2.8	10.7	S.D. 1.8	106.05
			P-Valu	ue≤0.01			

Table(5.23): The Mean Durations of the Preceding Vowel /a/ and the Following Voiceless Geminate Consonants /CC/ Followed by a Long Vowel

#### Pronounced in Words of the Pattern /fa \'Saal/

#### **Produced in Isolation**

Sequence	/a/		/(	/CC/		/aa/	F-Value			
/-t'taa-/	6.45	S.D. 1.5	22.1	S.D. 3.4	22.75	S.D. 6.2	48.084			
/-ţ'ţaa-/	7.05	S.D. 1.3	21.65	S.D. 3.6	25.4	S.D. 6.1	53.409			
/ <b>-ħ'ħaa</b> -/	7.1	S.D. 1.5	23.35	S.D. 2.9	24.6	S.D. 6.6	51.95			
	P-Value≤0.01									

# Table(5.24): The Mean Durations of the preceding Vowel /a/ and the Following Voiceless Geminate Consonants /CC/ Followed by a Long Vowel

#### Pronounced in Words of the Pattern /fasisaal/

Sequence	/a/		/	/CC/		/aa/				
/-t'taa-/	5.7	S.D. 0.78	19.4	S.D. 3.8	20.25	S.D.5.4	44.88			
/-ţ'ţaa-/	6.7	S.D 2.01.	19.55	S.D. 2.6	24.3	S.D.4.7	74.63			
/ <b>-ħ'ħaa</b> -/	6.55	S.D 0.64.	19.9	S.D. 2.6	22.4	S.D.4.7	72.74			
	P-Value≤0.01									

Table(5.25): The Mean Durations of the Preceding Vowel /a/ and the Following Voiced Geminate Consonants /CC/ Followed by a Short Vowel

#### Pronounced in Words of the Pattern /'fassal/

#### **Produced in Isolation**

Sequence	/a/		/	/CC/		/a/	F-Value			
/-zza-/	10.85	S.D.2.5	19.85	S.D.2.8	10.1	S.D.2.3	40.87			
/-mma-/	8.2	S.D.1.3	20.85	S.D.4.1	10.35	S.D.2.4	60.55			
/-rra-/	10.3	S.D.2.2	16.65	S.D.4.1	13.5	S.D.2.8	9.875			
/-lla-/	9.1	S.D.1.2	20.15	S.D.4.8	10.9	S.D.2.07	36.11			
	P-Value≤0.01									

## Table(5.26): The Mean Durations of the Preceding Vowel /a/ and the Following Voiced Geminate Consonants /CC/ Followed by a Short Vowel

#### Pronounced in Words of the Pattern /'fa\sal/

Sequence	/a/		/	/CC/		/a/	F-Value			
/-zza-/	10.45	S.D.1.5	16.95	S.D.2.9	9.9	S.D.2.3	25.031			
/-mma-/	7.8	S.D.1.9	19.1	S.D.3.6	7.9	S.D.2.2	62.79			
/-rra-/	9.5	S.D.1.9	14	S.D.3.5	11.8	S.D.2.6	6.45			
/-lla-/	8.6	S.D.1.4	16.6	S.D.3.03	10	S.D.1.7	38.56			
	P-Value≤0.01									

Table(5.27): The Mean Durations of the Preceding Vowel /a/ and the Following Voiced Geminate Consonants /CC/ Followed by a Long Vowel

#### Pronounced in Words of the Pattern /fa \'Saal/

#### **Produced in Isolation**

Sequence	/a/		/(	/CC/		/aa/	F-Value			
/-z¹zaa-/	8.05	S.D.0.92	18.4	S.D.2.5	25.1	S.D.6.6	42.97			
/-m'maa-/	6.6	S.D.1.3	19.3	S.D.2.5	24.3	S.D.4.8	78.16			
/-r'raa-/	7.35	S.D.1.2	15.9	S.D.3.05	25.3	S.D.7.05	39.93			
/-l'laa-/	7.35	S.D.1.5	19.15	S.D.3.5	22.8	S.D.5.7	40.46			
	P-Value≤0.01									

Table(5.28): The Mean Durations of the Preceding Vowel /a/ and the Following Voiced Geminate Consonants /CC/ Followed by a Long Vowel

#### Pronounced in Words of the Pattern /fasisaal/

Sequence	/a/		/(	/CC/		na/	F-Value			
/-z'zaa-/	7.95	S.D.0.64	16.8	S.D.3.2	21.45	S.D.3.9	52.57			
/-m'maa-/	5.9	S.D.1.07	16.25	S.D.2.7	22.65	S.D.5.5	54.55			
/-r'raa-/	7	S.D.0.66	13.15	S.D.2.5	23.1	S.D.4.9	62.44			
/-l'laa-/	6.55	S.D.1.2	15.3	S.D.2.05	20.7	S.D.3.9	70.99			
	P-Value≤0.01									

Table(5.29): The Mean Durations of the Preceding Voiceless Single Consonants /C/ Preceded by a Short Vowel and the Following Vowel /a/

#### Pronounced in Words of the Pattern /'fa\al/

#### **Produced in Isolation**

Sequence	/a/			/C/		/a/	F-Value			
/-aq-/	9.1	S.D.2.3	9.65	S.D.0.62	13.15	S.D.2.7	10.91			
/-as-/	8.35	S.D.2.05	11.55	S.D.2.03	11.65	S.D.1.8	13.63			
/-aș-/	9.05	S.D.2.7	11.4	S.D.1.8	12.7	S.D.3.05	5.04			
	P-Value≤0.01									

#### Table(5.30): The Mean Durations of the Preceding Voiceless Single Consonants /C/ Preceded by a Short Vowel and the Following Vowel /a/

#### Pronounced in Words of the Pattern /'faSal/

Sequence	/a/		,	/C/		/a/	F-Value			
/-aq-/	8.2	S.D.1.3	9.3	S.D.1.2	11.4	S.D.1.5	13.32			
/-as-/	7.9	S.D.1.5	10.35	S.D.1.5	10.15	S.D.1.5	7.75			
/-aș-/	8.8	S.D.1.6	10.45	S.D.1.3	11.15	S.D.2.4	60.05			
	P-Value≤0.01									

Table(5.31): The Mean Durations of the Preceding Voiceless Single Consonants /C/ Preceded by a Long Vowel and the Following Vowel /a/

#### Pronounced in Words of the Pattern /'faa\al/

#### **Produced in Isolation**

Sequence	/	'aa/	/C/		/a/		F-Value			
/-aaq-/	21.2	S.D.4.9	10.4	S.D.1.1	10.55	S.D.1.6	40.72			
/-aas-/	21.55	S.D.5.8	12.85	S.D.1.8	8.9	S.D.1.7	31.06			
/-aaș-/	20.45	S.D.5.2	12.75	S.D.1.2	8.85	S.D.1.9	31.113			
	P-Value≤0.01									

Table(5.32): The Mean Durations of the Preceding Voiceless Single Consonants /C/ Preceded by a Long Vowel and the Following Vowel /a/

#### Pronounced in Words of the Pattern /'faa\al/

Sequence	,	/aa/		/C/	/a/		F-Value			
/-aaq-/	18.05	S.D.4.03	9.4	S.D.0.90	8.9	S.D.0.80	44.79			
/-aas-/	19.2	S.D.4.6	11.35	S.D.1.9	7.8	S.D.1.1	38.57			
/-aaș-/	19.15	S.D.4.4	11.4	S.D.1.6	7.65	S.D.1.2	46.05			
	P-Value≤0.01									

Table(5.33): The Mean Durations of the Preceding Voiced Single Consonants /C/ Preceded by a Short Vowel and the Following Vowel /a/

#### Pronounced in Words of the Pattern /'fa\al/

#### **Produced in Isolation**

Sequence	/	'a/	/	<b>C</b> /	C/ /a/		F-Value		
/-a <b>r</b> -/	11.35	S.D.2.4	7.7	S.D.1.1	12.7	S.D.2.8	12.98		
/-adʒ-/	10.95	S.D.2.6	9.25	S.D.1.1	11.95	S.D.2.4	3.43		
P-Value<0.05									

Table(5.34): The Mean Durations of the Preceding Voiced Single Consonants /C/ Preceded by a Short Vowel and the Following Vowel /a/

#### Pronounced in Words of the Pattern /'fa\al/

Sequence	/a/			/C/		a/	F-Value		
/-ar-/	9.8	S.D.1.8	6.3	S.D.0.67	11.75	S.D.2.5	22.062		
/-a <b>d</b> 3-/	10.9	S.D.2.01	8.45	S.D.0.83	10.05	S.D.2.9	60.05		
P-Value<0.01									

Table(5.35): The Mean Durations of the Preceding Voiced Single Consonants /C/ Preceded by a Long Vowel and the Following Vowel /a/

#### Pronounced in Words of the Pattern /'faa\al/

#### **Produced in Isolation**

Sequence	/aa/		/(	/C/		/a/	F-Value		
/-aa <b>r</b> -/	25	S.D.6.2	8.35	S.D.1.3	9.4	S.D.1.5	60.05		
/-aadʒ-/	23.8	S.D.5.8	9.2	8.4	S.D.1.8	93.26			
P-Value≤0.01									

#### Table(5.36): The Mean Durations of the Preceding Voiced Single Consonants /C/ Preceded by a Long Vowel and the Following Vowel /a/

#### Pronounced in Words of the Pattern /'faa\al/

Sequence	/aa/			/C/		a/	F-Value		
/-aa <b>r</b> -/	22.05	S.D.4.3	7.75	S.D.1.4	8.35	S.D.1.2	57.80		
/-aad3-/	22.25	S.D.4.09	8.2	S.D.1.4	7.65	S.D.1.7	46.05		
P-Value≤0.01									

#### 5.4 Discussion of Results

Arabic, like other languages, has its own temporal properties in as far as the segmental duration is concerned. Since the basic aim of this study is to prove the existence of temporal compensation process in Arabic syllable structures, the present experiment has focused on testing a number of Arabic word patterns in order to detect the way the durations of contiguous segments compensate for each other interchangeably. Based on the results extracted from the sound spectrograms alongside the waveforms, it appears quite evident that the Arabic phonological segments compensate for the durational variation to which they are subjected under certain circumstances to maintain the overall duration relatively constant. Actually, a number of conclusions have been arrived at by the researcher.

#### 5.4.1 The Durational Contrasts of Single Versus Geminate Consonants

The results yield that geminate consonants, whether they are voiceless or voiced, are longer than their non-geminate counterparts when occurring in the same phonetic context. Moreover, it is observed that a geminate consonant is relatively more than twice the length of its non-geminate partner, whether they are pronounced in isolation or within a phonetic context. See figs. (5.1-5.4) for more illustration. A finding as such is affirmed by a number of researchers like Fujisaki et al. (1975); Hassan (1981); and Ghalib (1984) among others. Throughout this experiment, it is found that the durations of all the inspected consonantal types affirm the finding mentioned above. Consequently, the measurements of the durations of voiceless denti-alveolar and velar plosives /t/ vs. /tt/ and /k/ vs. /kk/, the voiced denti-alveolar plosive /d/ vs. /dd/, the voiceless labio-dental and palato-alveolar fricatives /ð/ vs. /ðð/ and /ʃ/ vs. /ʃʃʃ/, the voiced palato-alveolar affricate /dʒ/ vs. /dʒdʒ/ and the voiced bilabial nasal /m/ vs. /mm/, all occurring medially, reveal extremely obvious durational distinctions between single and geminate

consonants whether they are pronounced in isolated words or within words enunciated in a carrier sentence. This result is in complete agreement with those obtained by McKay,1980; Hassan, 1981,2002; Ghalib,1984; Giovanardi and Di Benedetto,1998; Mattie and Di Benedetto,2000; Faluschi and Di Benedetto,2001. For instance, McKay (op.cit.), in an investigation of geminate plosives in Rembarrnga, has found out that geminate plosives are significantly longer than their single counterparts because the 'occlusion' duration of the geminate plosive appears to be longer than that of its non-geminate cognate. More specifically, Hassan (1981) has contended that the articulation of a voiceless geminate plosive is characterized by a closure duration longer than that of its non-geminate counterpart. Mattie and Di Benedetto (op.cit.) have found out that, in Italian, geminate nasals are longer than their single partners.

The results of the present experiment are closely compatible with those of Mattie and Di Benedetto (ibid) in as far as the duration of the nasal consonant /m/ versus /mm/ is concernred. That is to say, the duration of /mm/ is very significantly longer than its single partner. Ghalib (op.cit.) acoustically and articulatorily has discovered that geminate consonants, whether occurring in wordinitial or in word-medial positions, are considerably longer than their non-geminate cognates, and that the duration of a geminate fricative is twice the length of its single partner. Moreover, he has found out that the closure duration of the voiced denti-alveolar geminate plosive /dd/ equals nearly three or four times the length of its non-geminate counterpart (Ghalib, op.cit.: 176). In an agreement with Ghalib (op.cit.), Hassan (2002), in an acoustic study, has inspected gemination in Arabic and Swedish. He has contended that the duration of a geminate consonant is very significantly longer than that of its non-geminate opposite in both languages examined. In an acoustic study to investigate geminate fricatives in Italian, Giovanardi and Di Benedetto (op.cit.:12) have maintained that geminates are longer than their non-geminate partners. Besides, Faluschi and Di Benedetto (op.cit.), in an acoustic investigation o Italian geminate affricates, have

observed that geminate affricates have longer durations than their non-geminate partners. Notwithstanding, the results obtained by Gordon et al. (1997) are incompatible with those of the present experiment. They have observed that, in Chickasaw, the durational difference between non-geminate and geminate consonants is smaller than that in Arabic.

What is more, the results of the present experiment also signify that voiceless consonants, no matter whether they are single or geminate, are longer than the voiced ones. For instance, Braunschweiler (1997) has affirmed that the closure durations of voiced plosives are shorter than those of the voiceless ones. Yet, this could not be associated with the lengthening of the preceding vowel duration.

Nevertheless, the main interest of this research is not only to examine the durational differences between single versus geminate consonants. Instead, it concentrates on the inspection of the reciprocal effect that dominates between adjacent vowel and consonant durations, i.e. how they compensate for the durational variations they undergo so that the syllable, and in turn, the word overall duration can be kept relatively constant.

#### 5.4.2 The Preceding and the Following Vowel Durations

The acoustic measurements disclose that vowel /a/ duration exposes insignificant durational variation when it is positioned before a single versus geminate consonant. In other words, the effect of the postvocalic consonant on the duration of the preceding vowel appears to be negligible. For instance, the tables (5.5) and (5.6) show that the mean durations of vowel /a/ before the labio-dental fricative /f/ in /'nafað/ versus /ff/ in /'naffað/ when uttered in isolation are 9.3 csec. and 9.45 csec., and its mean durations when the words are enunciated in a carrier sentence are 8.35 csec. and 8.85 csec. As as result, the duration of the preceding vowel exposes little evidence of temporal compensation when it occurs before single versus geminate consonants. This is also emphasized by Port et al. (1980), i.e. they have concluded that Arabic shows up minimal evidence of temporal

compensation between the duration of the preceding vowel and that of the following consonant. The present results partly coincide with those experimentally attained by Ghalib (op.cit.:178) in as far as the duration of the preceding vowel is concerned. He has observed that the durations of the preceding vowel in addition to the following vowel showed insignificant durational differences when occurring before single versus geminate consonants. He has found out that, in I.C. Arabic, the durations of the preceding and the following vowels occurring in stressed positions are not affected by the duration of the adjacent geminate consonant. That is to say, they maintain their 'original' durations when uttered in isolation and in a carrier sentence. McKay (op.cit.:346) has explained that the preceding vowel duration is not influenced by the duration of the following geminate consonant.

However, these results contradict those introduced by other researchers (e.g. Hassan, 1981,2002,2003; Maddieson,1985; Mattie and Di Benedetto,op.cit.; and Faluschi and Di Benedetto, op. cit.). Hassan (1981), in his experimental study of vowel duration in Iraqi spoken Arabic, has pointed out that in monosyllabic words, the vowels preceding single consonants tend to be longer than those preceding geminate ones even though the difference is small, it is deemed to be significant. Investigating gemination and its effect on the preceding vowel duration in Arabic and Swedish, Hassan (2002) has noticed that, in Arabic, vowels before single consonants are slightly longer than those before geminate consonants; whereas, in Swedish, the vowel duration before single consonants is significantly longer than that before geminate ones. As a result, the lengthening of the preceding vowel in Swedish is considered to be a language-specific pattern which has to be learned by Swedish speakers. In this connection, Hassan (ibid:82) has explained that "it does seem feasible to speculate that consonant length as well as vowel length in Swedish, in the phonetic context investigated are language specific phenomena, i.e. maintained by Swedish speakers for phonological purposes." However, Hassan (ibid), has remaked that the slight shortening of vowel duration before a geminate consonant, in Arabic, is a universal phenomenon which is attributed to

the 'articulatory' and 'aerodynamic' nature of gemination. Hassan (2003) has also inspected temporal compensation in Arabic and Swedish. He has maintained that there is a very significant difference between the preceding vowel duration and the following consonant in Swedish; therefore, it reveals obvious compensatory effort. Yet, in Arabic, the difference appears to be insignificant. As a result, the Arabic language, according to him, exhibits little evidence of temporal compensation.

Mattie and Di Benedetto (op.cit.11) have contended that the geminate nasals, in Italian, tend to shorten the preceding vowel duration. In addition, Faluschi and Di Benedetto (op.cit.) have confirmed that the long durations of the geminate affricates, in Italian, is compensated for by shortening the preceding vowel duration. More to the point, the present results also contradict those obtained by Gordon et al. (op.cit.). In an acoustic investigation of the phonetic features of Chickasaw, they have stressed that vowels occurring before non-geminate consonants are significantly longer than those occurring before geminate consonants; particularly, before single versus geminate bilabial plosives (Gordon,ibid:21). Flemming (1997) has remarked that this pattern of temporal compensation, where the preceding vowel is affected by the following consonant duration, is evidently observed in the duration variation of vowel /a/ more than in the other vowels. Conversely, depending on the measurements of the present experiment, it is found that the preceding vowel /a/ reveals negligible compensatory effort when it is positioned before single versus geminate consonants. Such a finding distinguishes the temporal pattern of the Arabic language from that of some other languages.

Differently, it is found that the following vowel duration shows evident compensatory effect, i.e. it compensates for the prevocalic consonant durational variation. See figs. (5.5-5.8). Thus, it is observed that the following vowel tends to lengthen after a single consonant, but it shortens after its geminate counterpart irrespective of the prevocalic consonant voicing feature. For example, tables (5.11)

and (5.12) expose that the average values of the vowel /a/ after /dʒ/ in /'radʒa\$/ when produced in isolation and within a context are 10.95 csec. and 10.05 csec.; whereas its mean durations after/dzdz/ in /'radzdzas/ when spoken in isolation and within a phonetic environment are 8.2 csec. and 7.8 csec. Yet, Ghalib (op.cit.) has observed that the following vowel duration is only slightly longer, though insignificantly, after the initial fricative /s/ rather than after /ss/. The results of the present experiment are partly compatible with those of Port et al. (op.cit.) and Giovanardi and Di Benedetto (op.cit.) in as far as the duration of the following vowel is concerned. In an experiment to inspect timing compensation in Japanese, Port et al. (op.cit.) have found out that the following vowel as well as the prevocalic consonant undergo durational adjustment. Similarly, Giovanardi and Di Benedetto (op.cit.;12) have found out that increasing consonant duration (a geminate) results in shortening the duration of the preceding vowel in addition to the following vowel duration. This finding sets Arabic away from some other languages, like English, Swedish and Japanese. Thus, in Arabic, it is the following vowel which is affected by the prevocalic consonant duration.

Moreover, it is discovered that the lengthening of the following vowel is compensated for by shortening the preceding single consonant duration; whereas the shortening of the following vowel is compensated for by the long duration of the prevocalic geminate consonant. For instance, the mean durations of the preceding single voiced denti-alveolar fricative /z/ and the following /a/-sound in /'χazan/ when uttered in isolation are 8.65 csec. and 13 csec., respectively. And when the word produced in a carrier sentence their mean durations are 7.75 csec. and 11.65 csec., respectively. However, the mean durations of the prevocalic /zz/ and following /a/ in /'χazzan/ when enunciated in isolation are 19.85 csec. and 10.1 csec.; besides, the mean durations as the word spoken in a carrier sentence are 16.95 csec. and 8.75 csec. Conversely, the mean durations of the preceding /dʒ/

and the following vowel /a/ in /'radʒas/ reveal nonsignificant durational variation when the word is produced in isolation and within context. Thus, their mean values when enunciated in an isolated word, are 9.25 csec. and 10.95 csec. And in a carrier sentence, their mean durations are 8.45 csec. and 10.05 csec., respectively. Still, tables (5.18) and (5.20) signify considerably significant durational differences which are shown by the preceding geminate /dʒdʒ/ and the following /a/-sound in /'radʒdʒas/ where their mean durations when the word is said in isolation are 21.15 csec. and 8.2 csec. And in a carrier sentence, their mean durations are 17.85 csec. and 7.8 csec.

Nonetheless, the vowel /a/, in Arabic, does not expose noticeable durational differences both before and after voiceless versus voiced consonants. That is to say, the durations of the preceding and the following vowels are not affected by the voicing feature of the adjacent consonant. For example, it is found that the vowel /a/ insignificantly varies its duration before the voiceless denti-alveolar plosive /t/ and its voiced counterpart /d/. Thus, the mean durations of vowel /a/ before /t/ in /'fatah/ and /d/ in /'hadaθ/ when spoken in isolation are 8.45 csec. and 8.9 csec. And when the words are said in a carrier sentence, its mean durations are 7.85 csec. and 8.15 csec. Similarly, the /a/-sound shows negligible durational variations before the geminates /tt/ vs. /dd/. As a consequence, the mean durations of the preceding /a/- sound before /tt/ in /'fattaħ/ and /dd/ in /'ħaddaθ/ when uttered in isolation are 8.15 csec. and 8.6 csec. And its mean durations when the words are enunciated within context are 7.75 csec. and 8.45 csec., respectively. See tables (5.5-5.8). Contrary to that, Port et al. (op.cit.:239) contend that the voicing feature of the following consonant influences the preceding vowel when occurring before /t/ vs. /d/. In agreement with the results obtained by Port et al. (ibid), Nagai (1996) has affirmed that vowels preceding voiced consonants are found to be longer than those preceding voiceless ones. In addition, Nagai (op.cit.) explains that the

syllable, and in turn, the word overall duration is roughly maintained constant in spite of the voicing distinctions. Nagai (ibid:8) has emphasized that since voiced consonants are 'intrinsically' shorter than the voiceless consonants, the preceding vowel tends to be longer before the voiced ones in order to compensate for the shorter duration of the following voiced consonant.

Regarding the following vowel /a/ duration, it is noticed that it reveals statistically nonsigificant durational variations as it occurs after the voiceless dentialveolar plosive /t/ and its voiced counterpart /d/. Consequently, the mean durations of /a/-sound after /t/ in /'fatah/ and /d/ in /'hada $\theta$ / when the words are produced in isolation are 10.55 csec. and 12.3 csec. Yet, the vowel /a/ expresses significant variation at p-value less than 0.05 (p<0.05) when the words in question are uttered in a carrier sentence. Thus, its mean durations after /t/ vs. /d/ are 9.25 csec. and 11.65 csec., respectively.

In the case of the geminates /tt/ vs. /dd/, the vowel /a/ displays insignificant durational difference when pronounced within words produced both in isolation and in a carrier sentence. The measurements show that the mean durations of /a/sound after /tt/ in /'fattah/ and /d/ in /'haddaθ/ when said in isolation are 8.2 csec. and 8.95 csec. And its mean durations, as the words are spoken in a carrier sentence, are 7.7 csec. and 8.25 csec., respectively. See tables (5.9-5.12). This result agrees with Morrison's (2002) contention. Morrison (ibid:18) reports that Arabic native speakers insignificantly vary vowel duration in accordance with the voicing characteristic of the adjacent consonant.

Nevertheless, such a finding contradicts the results obtained by Nagai (1996) and Braunschweiler (1997) in as far as the voicing effect on vowel duration is considered. To come closer to the point, they have affirmed that vowels preceding voiced consonants are found to be longer than those before voiceless ones.

#### 5.4.3 The Preceding Vowel Duration Followed by /-CCa-/-Sequences Versus

#### /-CCaa-/-Sequences

The acoustic measurements signify that there is interdependent relationship between the preceding vowel duration and the segment sequences next to it. More specifically, the duration of the preceding vowel /a/ is affected by the duration of the following geminate consonant which is followed either by a short or long vowel. It is noticed that the vowel /a/ occurring before a geminate consonant followed by a short vowel is longer than that occurring before a geminate consonant followed by a long vowel. For instance, tables (5.21-5.24) exhibit that the mean durations of /a/-sound before the voiceless geminate pharyngeal fricative followed by a short vowel /-ħħa-/ in /'raħħal/ when spoken in isolation and in a carrier sentence are 9.7 csec. and 8.3 csec.; whereas its mean durations before /-h'haa-/-sequence in /rah'haal/ when said in isolation and in a carrier sentence are 7.1 csec. and 6.55 csec., respectively. Therefore, the /a/-sound before /-ħħa-/sequence is longer than that before /-h'haa-/-sequence. Similarly, the /a/-sound tends to lengthen when it occurs before the geminate flap /rr/ followed by a short vowel rather than before /rr/-sound followed by a long vowel. The results display that the vowel /a/ durations before the geminate flap followed by a short vowel /-rra-/ used in /\footnotesia are 10.3 csec. and 9.5 csec.; while its mean durations before /-r'raa-/-sequence pronounced in /\fortraaf / when uttered in isolation and within a phonetic environment are 7.35 csec. and 7 csec. This definitely leads to the deduction that the vowel /a/ duration is influenced by its position within the syllable, i.e. its duration is affected by the durations of the adjacent segments (in this case the following geminate consonant in addition to the vowel next to it as to whether it is long or short) and the stress degree (Malmberg, 1963; and Jones, 1967).

Considering the two examples mentioned above, it can be easily recognized that the vowel /a/ occurring in the first stressed syllable before /-ħħa-/-sequence is longer than that occurring in the first unstressed syllable before /-ħħa-/-sequence because, in the former sequence, it is followed by a geminate attached to a short vowel; whereas, in the latter, it is followed by a geminate attached to a long vowel. And this is also true of /a/-sound before /-rra-/-sequence in /\subseteq arra-f vs. /-r'raa-/-sequence in /\subseteq arra-f vs. /-r'raa-/-sequence of the structure /-CCa-/ than before /-C'Caa-/ in the same phonetic context. Still, the preceding vowel /a/ shows negligible durational difference in relation to the voicing feature of the following geminate consonants.

#### 5.4.4 The Following Vowel Duration Preceded by /-aC-/-Sequences Versus

#### /-aaC-/- Sequences

The results expose that the Arabic vowel /a/ tends to be longer after a single consonant preceded by a short vowel (/-aC-/-sequence) than after a single consonant preceded by a long vowel (/-aaC-/-sequence). For example, the vowel /a/ after the uvular plosive /q/ preceded by a short vowel /-aq-/ is longer than that after /q/ preceded by a long vowel /-aaq-/. Based on the acoustic measurements displayed in tables (5.29-5.32), it is found that the mean durations of /a/-sound after /-aq-/ in /'naqaf/ when produced in isolation and in a carrier sentence are 13.15 csec. and 11.4 csec.; while its mean durations after /-aaq-/ when spoken in isolation and within a carrier sentence are 10.35 csec. and 8.9 csec., respectively. This finding obviously uncovers the effect of the durations of contiguous sounds on each other durations. Regarding the example mentioned above, the lengthening of the following vowel /a/ is compensated for by shortening the duration of the preceding sequence /-aq-/, whereas the shortening of the following vowel /a/ duration is compensated for by the long duration of the preceding sequence /-aaq-/.

The voicing feature exposes insignificant effect on the following vowel duration. That is to say, the vowel, whether occurring after a voiced versus voiceless consonant, reveals negligible durational variation. For instance, the mean durations of vowel /a/ after /-as-/-sequence pronounced in /'hasab/ and /-aʁ-/-sequence used in /'ʃaʁal/ when produced in isolation are 11.9 csec. and 12.7 csec. And its mean durations, as the words are said in a carrier sentence, are 10.15 csec. and 11.75 csec., respectively. In the same way, the mean durations of vowel /a/ after /-aas-/-sequence in /'ħaasab/ and /-aaʁ-/-sequence in /'ʃaaʁal/ when both are uttered in isolation are 8.9 csec. and 9.4, and its mean durations when the words are enunciated in a carrier sentence, are 7.8 csec. and 8.35 csec., respectively.

#### 5.5 Conclusions

Throughout the present research, the acoustic experiment, which represents the essential part of this project, proves that there is categorically obvious evidence of temporal compensation phenomenon within certain syllabic structure patterns in MSA, and that the Arabic language has its own temporal model which sets it apart from the other languages. To come closer to the point, the Arabic phonological segments exhibit a characteristic timing compensation model different from that in other languages, like English, Italian, Norwegian, Estonian, German, etc., where the compensatory effort is extremely evident in the durational change of the preceding vowel. The acoustic measurements of the present study show up the opposite finding. That is to say, it is the following vowel which is considerably affected by the duration of the prevocalic consonant, i.e. whether it is single or geminate. Additionally, vowel duration is highly significantly influenced by the durations of the adjacent sound sequences. As it was previously mentioned, such a phenomenon, viz. temporal compensation, is found to be quite essentially dependent on segmental duration which is acoustically tested. On the basis of the extracted results, a set of conclusions are derived as follows:

- 1. The results emphasize the durational differences between non-geminate and geminate consonants. That is to say, the measurements affirm that geminate consonants are considerably longer than their single counterparts, no matter whether they are voiceless or voiced, when occurring in the same phonetic contexts. In addition, it is also discovered that voiceless consonants are longer than the voiced ones.
- 2. In most languages, the acoustic studies have revealed that it is the preceding vowel duration which is highly influenced by the duration of the post vocalic consonant where it either lengthens or shortens its duration. In Arabic; however, the vowel duration exposes negligible durational variations when it precedes a single versus geminate consonant though its duration still appears shorter than that of a doubled consonant.
- 3. Conversely, the acoustic measurements disclose a striking finding concerning the duration of the following vowel. It is found out that the duration of the following vowel exposes considerably significant durational differences when it is positioned after single versus geminate consonants. More specifically, the following vowel tends to lengthen after a single consonant; whereas it tends to shorten after its geminate cognate. This finding uncovers an important compensatory effort that takes place between the prevocalic consonant and the following vowel durations. In fact, the following vowel tends to lengthen in order to compensate for the short duration of the preceding single consonant; but it compensates for the long duration of the preceding geminate consonant by performing a shortening compensatory process.
- 4. It is also discovered that the syllabic structure is highly influential, i.e. the position of the vowel in relation to the other segments within the syllable where they cluster plays an important role in varying vowel duration. On the basis of the results extracted from the spectrograms accompanied by waveforms, it is discovered that the vowel occurring before a geminate consonant followed by

a short vowel is longer than that occurring before a geminate consonant followed by a long vowel. Apparently, the preceding vowel displays an obvious evidence of compensatory lengthening effort before the /-CCa-/-sequence; whereas it exposes a compensatory shortening effort before /-CCaa-/-sequence, since the former sequence is characterized by shorter duration than the latter one.

- 5. The following vowel displays overwhelmingly significant durational differences when it occurs after a single consonant preceded by a short vowel (/-aC-/-sequence) in comparison to that occurring after a single consonant preceded by a long vowel (/-aaC-/-sequence). In other words, since the former sequence is shorter than the latter one, the following vowel tends to lengthen after /-aC-/-sequences, whereas it tends to shorten after /-aaC-/-sequences. This definitely indicates the existence of the timing compensation process.
- 6. The preceding and the following vowel durations are not influenced by the voicing feature of the adjacent consonant. Thus, they display negligible durational differences when occurring before and after a voiceless versus voiced consonant regardless of its being a non-geminate or geminate consonant.

#### 5.6 Suggestions for Future Research

Although the stimulus items selected for performing the present acoustic experiment almost represent the most basic syllabic structure patterns in the Arabic language, they help validate the presence of the temporal compensation mechanism within these structures. Thus, it seems beneficial to suggest the following research topics for future research:

1. The results of this thesis point out to the need for additional research to be made for investigating the timing compensation process within Arabic syllable structures containing the other two Arabic vowels, namely /i/ and /u/, in the vicinity of specific consonantal types indicating non-geminate versus geminate

- contrasts and occurring in different positions, i.e. whether they occur in word-initial, word-medial or in word-final position (Ghalib,1984; van Son and van Santen,1997; de Lacy,1998; and Hassan, 2002).
- 2. It is also suggested that comparative studies on the existence of the temporal compensation phenomenon can be conducted in different Arabic dialects, for example, Iraqi, Cairene, Moroccan, and Lebanese Colloquial Arabic, ..., etc. as compared to MSA (van Leyden,2002; and Hassan,2003).
- 3. Besides, the findings of this research suggest conducting studies on a set of different factors affecting the segmental duration in Arabic, such as the voicing feature, manner and place of articulation, vowel quality, the phonetic context, syllable structure and stress patterns, speech rate,...,etc. More specifically, it is recommended to study them in combination, i.e. the way they interact to affect segmental duration (van Son and van Santen,1997; Botinis et al.,2002; and Zafeiri,2002-2003).
- 4. A production study may be carried out to examine databases extracted from normal-speaking and disordered-speaking participants in order to explore the distinct temporal properties that characterize the timing compensation model of the speech of both groups (Fujisaki et al.,1975). A further database may be extracted from normal-speaking children for the purpose of inspecting the developmental stages whereby the children acquire the speech temporal aspects similar to those of the adult speech model (Kuijpers,1993).
- 5. It is valuable to conduct a perceptual study on manipulating vowel duration as a cue for distinguishing consonant length contrasts, i.e. whether they are long (geminate) or short (single) (Obrecht, 1965).
- 6. It appears quite valuable to use the Speech Filing System computer software which facilitates employing spectrograms alongside waveforms of isolated segments and segments produced within certain phonetic contexts in further sophisticated purely phonetic or phonological studies.

## Appendix-A

The complete wordlists read by the speakers during the recording sessions.

## القائمة الاولى

وَصِلَ وَاصِلَ	7 7	فتَح فَتَّح	١
خَالْط خَلاَط	7 £	فَتَّح فَتًاح	7
خَزَن خَزَن	70	صدَق صادَق	٣
حَمَّل حَمَّال	77	سكابق سنبًاق	£
نزل ثازل	**	حَدَث حَدَّث	٥
عَالَم عَلاَّم	4.4	هَدَم هَدَّام	٦
حَشْدَ حَشْدً	79	شكطر شكاطر	٧
حَلَّق حَلاَّق	٣٠	صابر صباً	٨
شكك شكاغل	٣١	نَظْم نَظَّم	٩
زَاول زَوَّال	٣٢	عَطْر عَطَار	١.
رَجَع رَجَع	44	نَقَشَ نَاقَش	11
عَلَّم عَلاَّم	٣٤	غادر غدًار	١٢
رَجَع رَاجَع	٣٥	دُکَر دُکَّر	١٣
عَاوَد عَوَّاد	44	خَزَّن خَزَّان	١٤
حَمَل حَمَّل	٣٧	صَفَح صَافَح	10
عَرَّف عَرَّاف	٣٨	نَاقَش نَقَاش	١٦
ستمتح ستامتح	٣٩	وَقع وَقع	١٧
سایر سنیار	٤.	نَشَّفُ نَشَّافُ	١٨
		حَسنَب حَاسنَب	١٩
		نَازَع نَزًاع	۲.
		نَقَدُ نَقَدُ	۲١
		رَحَّل رَحَّال	* * *

## القائمة الثانية

وكصل وكاصل	7 7	سابق سببًاق	١
رَحَّل رَحَّال	7 £	فَتَح فَتَّح	۲
عَالَم عَلاَّم	70	صدق صادق	٣
خزَن خزرَن	77	فُتَّح فَتَّاح	٤
ئزل ئازل	**	صابر صباً	٥
حَمَّل حَمَّال	۲۸	حَدَثْ حَدَّث	٦
زَاوَل زَوَّال	79	شكطر شكاطر	٧
حَشْدَ حَشْدَ	٣.	هَدَّم هَدَّام	٨
شَعَل شَاعْل	٣١	غادر غدًار	٩
حَلَق حَلاق	**	نظم نظم	١.
عَاوَد عَوَّاد	44	نَقْش نَاقش	11
رَجَع رَجَّع	٣٤	عطر عطار	١٢
رَجَع رَاجَع	٣٥	نَاقَش نَقَاش	١٣
عَلَّم عَلاَّم	44	دُکَر دُکَّر	١٤
ساير سنيًار	**	صَفَح صَافْح	10
حَمَل حَمَّل	٣٨	خَزَّن خَزَّان	١٦
سنَمَح سنَامَح	٣٩	نَازَع نَزًاع	١٧
عَرَّف عَرَّاف	٤.	وَقع وَقع	١٨
		حَسنب حَاسنب	۱۹
		نَشَّف نَشَّاف	۲.
		خَالَط خَالَاط	۲١
		نَقَدُ نَقَدُ	* *

## القائمة الاولى / الجمل

			I.
اقرا حَشّد ست مرات	۲ ٤	اقرا ساير ست مرات	١
اقرا عَالَم ست مرات	70	اقرا سيّار ست مرات	۲
اقرا عَلاَّم ست مرات	77	اقرا سمَح ست مرات	٣
اقرا نَزَل ستَ مرات	**	اقرا سامَح ست مرات	£
اقرا نازل ست مرات	۲۸	اقرا عَرَّف ست مرات	٥
اقرا حَمَّل ستَ مرات	79	اقرا عَرَّاف ست مرات	٦
اقرا حَمَّال ست مرات	٣.	اقرا حَمَل ست مرات	٧
اقرا خَزَن ست مرات	٣١	اقرا حَمَّل ست مرات	٨
اقرا خَزَّن ست مرات	* *	اقرا عاورد ست مرات	٩
اقرا خَالَط ست مرات	٣٣	اقرا عَوَّاد ست مرات	١.
اقرا خَلاَط ست مرات	٣ ٤	اقرا رَجَع ست مرات	١١
اقرا و صل ست مرات	40	اقرا رَاجَع ست مرات	١٢
اقرا و اصل ست مرات	٣٦	اقرا عَلَم ست مرات	١٣
اقرا رَحَّل ست مرات	**	اقرا عَلاَّم ست مرات	١ ٤
اقرا رحاً لست مرات	٣٨	اقرا رَجَع ست مرات	10
اقرا نَقَدْ ست مرات	٣٩	اقرا رَجَع ست مرات	١٦
اقرا نَقَدُ ستَ مرات	٤٠	اقرا ز اول ست مرات	1 ٧
اقرا نَازَع ست مرات	٤١	اقرا زوًال ست مرات	١٨
اقرا نُزَّاع ست مرات	٤٢	اقرا شَعَل ست مرات	١٩
اقرا حَسنب ست مرات	٤٣	اقرا شاعل ست مرات	۲.
اقرا حاسب ست مرات	££	اقرا حَلَق ست مرت	۲١
اقرا نَشَف ست مرات	٤٥	اقرا حَلاَق ست مرات	77
اقرا نَشَّاف ست مرات	٤٦	اقرا حَشْد ست مرات	77

٧٤         اقرا وقع ست مرات         ٧٧         اقرا وقع ست مرات           ٨٤         اقرا وقع ست مرات         ٧٧         اقرا سنبق ست مرات           ٩٠         اقرا انقش ست مرات         ٧٧         اقرا سنبق ست مرات           ١٥         اقرا صنف ست مرات         ١٥         اقرا صنف ست مرات           ٢٠         اقرا صنف ست مرات         ١٥         اقرا فقح ست مرات           ١٥         اقرا خرّن ست مرات         ١٨         اقرا فقح ست مرات           ١٥         اقرا نكر ست مرات         ١٨         اقرا فقح ست مرات           ١٥         اقرا نقش ست مرات         ١٠         اقرا فقح ست مرات           ١٥         اقرا نقش ست مرات         ١٠         اقرا نقش ست مرات           ١٦         اقرا نقش ست مرات         ١٠         ١٥           ١٦         اقرا نقش ست مرات         ١٠         ١٥           ١٦         اقرا نقش ست مرات         ١٠         ١٥           ١٦         اقرا صنابر ست مرات         ١٠         ١٥           ١٦         اقرا شنظ ست مرات         ١٥         ١٥           ١٥         اقرا شنظ ست مرات         ١٥         ١٥           ١٥         اقرا شنظ ست مرات         ١٥         ١٥           ١٥         اقرا شنظ ست مرات         ١٥         ١٥		1		1
9 القرائفش ست مرات         ٧٣         القراشائق ست مرات           ٠٠ القراشائق ست مرات         ١٠ القراصة ست مرات         ١٥ القراصة ست مرات           ١٥ القراصة ست مرات         ١٧ القراصة ست مرات           ٣٠ القراضة على ست مرات         ١٧٧ القرافة على ست مرات           ١٥٠ القرافة على ست مرات         ١٨٠ القرافة ست مرات           ١٥٠ القرافة ست مرات         ١٨٠ القرافة ست مرات           ١٥٠ القرافة ست مرات         ١٠ القرافة ست مرات           ١٠ القرافة ست مرات         ١٠ القرافة ست مرات           ١٢ القرافة ست مرات         ١٠ القرافة ست مرات           ١٢ القراضية ست مرات         ١٠ القراضة ست مرات           ١٢ القراضية ست مرات         ١٠ القراضة ست مرات           ١٢ القراضية ست مرات         ١٠ القراشة ست مرات           ١٢ القراشة ست مرات         ١٠ القراشة ست مرات           ١٢ القراشة ست مرات         ١٠ القراشة ست مرات           ١٢ القراشة ست مرات         ١٠ القراشة ست مرات           ١٨ القراشة ست مرات         ١٠ القراشة ست مرات           ١٨ القراشة ست مرات         ١١ القراشة ست مرات           ١٨ القراشة ست مرات         ١١ القراشة ست مرات	اقرا حدَث ست مرات	٧١	اقرا و قع ست مرات	٤٧
١٥         اقرا تقاش ست مرات         ١٠         اقرا صدّق ست مرات         ١٥         اقرا صدّق ست مرات         ١٠         اقرا صدّق ست مرات         ١٠         اقرا صدّق ست مرات         ١٠         اقرا فقّح ست مرات         ١٠         ١١	اقرا حَدَّث ست مرات	٧٢	اقرا وقع ست مرات	٤٨
10         اقرا صَفَح ست مرات         ١٥         اقرا صَدَق ست مرات           ٢٠         اقرا صَدَق ست مرات         ٢٧         اقرا فقّح ست مرات           ٢٠         اقرا خَرَّان ست مرات         ٢٧         اقرا فقّح ست مرات           ٥٠         اقرا خَرَّان ست مرات         ٢٠         اقرا فقح ست مرات           ٢٠         اقرا غاذر ست مرات         ١٠         اقرا غقر ست مرات           ٢٠         اقرا غذار ست مرات         ١٥           ٢٠         اقرا نقش ست مرات         ١١           ١٦         اقرا عظر ست مرات         ١١           ١٦         اقرا تظم ست مرات         ١١           ١٦         اقرا صَظر ست مرات         ١١           ١٥         اقرا صَبَار ست مرات         ١١           ١٦         اقرا صَبَار ست مرات         ١١           ١٥         اقرا شَطر ست مرات         ١٥           ١٥         اقرا هَمْ ست مرات         ١٥	اقرا سابق ست مرات	٧٣	اقرا نَاقش ست مرات	٤٩
١٥         اقرا صافح ست مرات         ١٥         اقرا فتَح ست مرات           ١٥         اقرا فتَرَّن ست مرات         ١٥         اقرا فتَح ست مرات           ١٥         اقرا فتَر ست مرات         ١٩         اقرا فتَح ست مرات           ١٥         اقرا فتَح ست مرات         ١٠         اقرا فتَح ست مرات           ١٥         اقرا غاذر ست مرات         ١٥         ١٥           ١٥         اقرا غقش ست مرات         ١٥         ١٥           ١٦         اقرا غظر ست مرات         ١٥         ١٥           ١٦         اقرا غظر ست مرات         ١٥         ١٥           ١٥         اقرا شظر ست مرات         ١٥         ١٥           ١٦         اقرا شظر ست مرات         ١٥         ١٥           ١٥         اقرا شظر ست مرات         ١٥         ١٥           ١٥         اقرا شطر ست مرات         ١٥         ١٥           ١٥         اقرا شطر ست مرات         ١٥         ١٥           ١٥         اقرا شاطر ست مرات         ١٥         ١٥           ١٥         اقرا شاطر ست مرات         ١٥         ١٥           ١٥         اقرا شام ست مرات         ١٥         ١٥	اقرا سنباق ست مرات	٧٤	اقرا نَقَاش ست مرات	٥,
٣٥         اقرا خَرَّنَ ست مرات         ٧٧         اقرا فَتَّح ست مرات           ٤٥         اقرا خَرَّان ست مرات         ٧٧         اقرا فَتَّح ست مرات           ٥٥         اقرا نكر ست مرات         ٠٨         اقرا فَتَّح ست مرات           ٧٥         اقرا غار ست مرات         ٠٨         اقرا غقر ست مرات           ٩٥         اقرا نقش ست مرات         ٠٠         اقرا غطر ست مرات           ٢٦         اقرا غطر ست مرات         ١٥         ١٥           ٣٢         اقرا نظم ست مرات         ١٥         ١٥           ٢٦         اقرا صَبَر ست مرات         ١٥         ١٥           ٢٦         اقرا سَبَر ست مرات         ١٥         ١٥           ٢٦         اقرا شَطر ست مرات         ١٥         ١٥           ٢٦         اقرا شَطر ست مرات         ١٥         ١٥           ٢٨         اقرا شَطر ست مرات         ١٥         ١٥           ٢٨         اقرا شَمَط ست مرات         ١٥         ١٥           ٢٩         اقرا شَمَط ست مرات         ١٥         ١٥           ٢٩         اقرا شَمَط ست مرات         ١٥         ١٥	اقرا صدق ست مرات	٧٥	اقرا صفّح ست مرات	٥١
١٥٥         اقرا خَزَان ست مرات         ١٥٥         اقرا فَتَح ست مرات           ١٥٥         اقرا نكر ست مرات         ١٥٠         اقرا فَتَح ست مرات           ١٥٠         اقرا غار ست مرات         ١٥٠         اقرا غقش ست مرات           ١٥٠         اقرا نقش ست مرات         ١٠٠         اقرا نقش ست مرات           ١٦٠         اقرا عَظر ست مرات         ١٦٠           ١٦٠         اقرا تظم ست مرات         ١٤٠           ١٥٠         اقرا صَابَر ست مرات           ١٦٠         اقرا صَابَر ست مرات           ١٦٠         اقرا شَطر ست مرات           ١٦٠         اقرا شَطر ست مرات           ١٥٠         اقرا شَطر ست مرات	اقرا صادق ست مرات	٧٦	اقرا صاقح ست مرات	٥٢
٥٥       اقرا نكر ست مرات       ١٥       اقرا فتح ست مرات         ٢٥       اقرا غادر ست مرات       ١٥       اقرا فتح ست مرات         ٨٥       اقرا غقر ست مرات       ١٠       اقرا نقش ست مرات         ٢٠       اقرا ناقش ست مرات       ١٦         ٢٦       اقرا غطر ست مرات       ١٦         ٣٦       اقرا غطر ست مرات       ١٥         ٢٠       اقرا صَابَر ست مرات         ٢٠       اقرا شَطر ست مرات	اقرا فُتَّح ست مرات	٧٧	اقرا خَزَّن ست مرات	٥٣
۲٥       اقرا اَعْرَ ست مرات         ۷٥       اقرا غائر ست مرات         ۸٥       اقرا غقر ست مرات         ۹٥       اقرا نقش ست مرات         ۲٠       اقرا نقش ست مرات         ۲۲       اقرا عَظر ست مرات         ۳۲       اقرا عَظر ست مرات         ۱۳       اقرا تَظم ست مرات         ۱۳       اقرا صَابَر ست مرات         ۲۶       اقرا صَابَر ست مرات         ۲۶       اقرا شَطر ست مرات         ۲۶       اقرا شَطر ست مرات         ۲۸       اقرا شَطر ست مرات         ۱۹       اقرا شَطر ست مرات         ۱۹       اقرا شَطر ست مرات         ۱۹       ۱قرا شَطر ست مرات	اقرا فُتَّاح ست مرات	٧٨	اقرا خَزَّان ستَ مرات	0 £
۱۵ اقرا غادر ست مرات ۱۹ اقرا غدار ست مرات ۱۹ اقرا نقش ست مرات ۱۳ اقرا ناقش ست مرات ۱۳ اقرا عَظر ست مرات ۱۳ اقرا نظم ست مرات ۱۳ اقرا شطّر ست مرات ۱۳ اقرا صابر ست مرات ۱۳ اقرا است مرات ۱۳ اقرا شاطر ست مرات	اقرا فُتَح ست مرات	٧٩	اقرا دُكر ست مرات	٥٥
اقرا غَدًار ست مرات         9       اقرا غَشْ ست مرات         ٠٠       اقرا غَشْ ست مرات         ١٦       اقرا عَظْر ست مرات         ٢٠       اقرا عَظْر ست مرات         ٣٠       اقرا نَظَم ست مرات         ١٥       اقرا صَابَر ست مرات         ٢٠       اقرا صَبَّار ست مرات         ٢٠       اقرا شَطْر ست مرات         ٢٠       اقرا شَطْر ست مرات         ١٥       اقرا شَطْر ست مرات         ١٥       اقرا هَدَّم ست مرات         ٢٩       اقرا هَدَّم ست مرات         ٢٩       اقرا هَدَّم ست مرات	اقرا فُتَّح ست مرات	٨٠	اقرا دُكَّر ست مرات	٥٦
90       اقرا نَقش ست مرات         7        اقرا نَاقش ست مرات         7 1       اقرا عَظر ست مرات         7 7       اقرا مَظر ست مرات         7 8       اقرا نظم ست مرات         8 7       اقرا شظم ست مرات         9 7       اقرا صباً رست مرات         7 7       اقرا شطر ست مرات         7 8       اقرا شطر ست مرات         7 9       اقرا شطر ست مرات         1 1       اقرا شاطر ست مرات         1 1       اقرا هَدًم ست مرات         1 1       اقرا هَدًم ست مرات         1 1       اقرا هَدًم ست مرات			اقرا عادر ست مرات	٥٧
١٠       اقرا أقش ست مرات         ١٦       اقرا عَظر ست مرات         ١٦       اقرا عَظار ست مرات         ١٦       اقرا نظم ست مرات         ١٥       اقرا صَابَر ست مرات         ١٦       اقرا صَابَر ست مرات         ١٦       اقرا شَطر ست مرات         ١٥       اقرا شَطر ست مرات         ١٥       اقرا شَاطر ست مرات         ١٥       اقرا شَاطر ست مرات         ١٥       اقرا شَاطر ست مرات         ١٩       اقرا هَدَّم ست مرات			اقرا عَدَّار ست مرات	٥٨
17       اقرا عَظر ست مرات         17       اقرا عَظار ست مرات         18       اقرا نظم ست مرات         15       اقرا شظم ست مرات         10       اقرا صَبَر ست مرات         17       اقرا صَبَر ست مرات         18       اقرا شَطر ست مرات         17       اقرا شَطر ست مرات         18       اقرا شَاطر ست مرات         18       اقرا شَاطر ست مرات         19       اقرا هَدَّم ست مرات			اقرا تَقَش ست مرات	٥٩
۱۲ اقرا عَطار ست مرات ۱۳ اقرا نظم ست مرات ۱۳ اقرا نظم ست مرات ۱۰ اقرا صابر ست مرات ۱۲ اقرا صابر ست مرات ۱۲ اقرا صبر ست مرات ۱۲ اقرا شبطر ست مرات ۱۲ اقرا شبطر ست مرات			اقرا نَاقش ست مرات	٦.
٦٣       اقرا نظم ست مرات         ١٤       اقرا تظم ست مرات         ١٥       اقرا صنبر ست مرات         ٢٦       اقرا صببار ست مرات         ٢٧       اقرا شنطر ست مرات         ٢٨       اقرا شناطر ست مرات         ١٥       ١٥         ١٥       ١٥         ١٥       ١٥         ١٥       ١٥         ١٥       ١٥         ١٥       ١٥         ١٥       ١٥         ١٥       ١٥         ١٥       ١٥			اقرا عَطْر ست مرات	71
١٥       اقرا نظم ست مرات         ١٥       اقرا صابر ست مرات         ١٦       اقرا صباً رست مرات         ١٧       اقرا شطر ست مرات         ١٨       اقرا شاطر ست مرات         ١٩       اقرا هَدَّم ست مرات         ١٩       اقرا هَدَّم ست مرات			اقرا عَطّار ست مرات	٦٢
اقرا صابر ست مرات اقرا صببًار ست مرات اقرا صببًار ست مرات اقرا شبطر ست مرات اقرا شبطر ست مرات اقرا شبطر ست مرات اقرا شباطر ست مرات اقرا شباطر ست مرات اقرا هَدَّم ست مرات القرا شبط القرا			اقرا نظم ست مرات	٦٣
٦٦       اقرا صبَاًر ست مرات         ٦٧       اقرا شَطَر ست مرات         ٦٨       اقرا شَاطر ست مرات         ١٩       اقرا هَدَّم ست مرات			اقرا نَظَم ست مرات	٦٤
٦٧       اقرا شَطَر ست مرات         ٦٨       اقرا شَاطَر ست مرات         ١٩       اقرا هَدَّم ست مرات			اقرا صابر ست مرات	70
۲۸ اقرا شاطر ست مرات ۱۹ اقرا هَدَّم ست مرات			اقرا صبَّار ست مرات	11
٦٩ اقرا هَدَّم ست مرات			اقرا شَطَر ست مرات	٦٧
			اقرا شاطر ست مرات	٦٨
، ۷ اقر ا هَدَّام سِيتَ مِي ات			اقرا هَدَّم ست مرات	٦٩
			اقرا هَدَّام ستَ مرات	٧٠

## القائمة الثانية /الجمل

اقرا خَزَّن ست مرات	7 £	اقرا صَفَح ست مرات	١
اقرا نَزَل ستَ مرات	40	اقرا صاقح ست مرات	۲
اقرا نازل ست مرات	41	اقرا خَزَّن ست مرات	٣
اقرا حَمَّل ستَ مرات	**	اقرا خَزَّان ستَ مرات	٤
اقرا حَمَّال ست مرات	۲۸	اقرا نَازَع ست مرات	٥
اقرا سابق ست مرات	49	اقرا نزاًع ست مرات	٦
اقرا سنبَّاق ست مرات	٣.	اقرا و قع ست مرات	٧
اقرا فتَح ست مرات	٣١	اقرا وقع ست مرات	٨
اقرا فتَّح ست مرات	٣٢	اقرا حَسنب ست مرات	٩
اقرا صدوق ست مرات	٣٣	اقرا حاسب ست مرات	١.
اقرا صادق ست مرات	٣ ٤	اقرا نَشَقَ ست مرات	11
اقرا فُتَّح ستَ مرات	٣٥	اقرا نَشَّاف ست مرات	١٢
اقرا فُتَّاح ست مرات	٣٦	اقرا خَالط ست مرات	١٣
اقرا صابر ست مرات	٣٧	اقرا خَلاَط ست مرات	١٤
اقرا صببًار ست مرات	٣٨	اقرا نَفَذ ست مرات	10
اقرا حَدَث ست مرات	٣٩	اقرا ثَقَدْ ستَ مرات	17
اقرا حدَّث ست مرات	٤٠	اقرا و صل ست مرات	۱۷
اقرا شُكِطر ست مرات	٤١	اقرا و اصل ست مرات	۱۸
اقرا شاطر ست مرات	٤٢	اقرا رَحَّل ست مرات	19
اقرا هَدَّم ست مرات	٤٣	اقرا رحاً لست مرات	۲.
اقرا هَدَّام ست مرات	££	اقرا عَالَم ست مرات	۲١
اقرا عادر ست مرات	٤٥	اقرا عَلاَّم ست مرات	4 4
اقرا غَدَّار ست مرات	٤٦	اقرا خَزَن ست مرات	7 7
	I		

	•	_	
اقرا عَلَم ست مرات	٧١	اقرا نَظْم ست مرات	٤٧
اقرا عَلاَم ست مرات	<b>٧ ٢</b>	اقرا نَظَم ست مرات	٤٨
اقرا سایر ست مرات	٧٣	اقرا نَقَش ست مرات	٤٩
اقرا سياًر ست مرات	٧٤	اقرا نَاقش ست مرات	٥,
اقرا حَمَل ست مرات	٧٥	اقرا عطر ست مرات	٥١
اقرا حَمَّل ست مرات	٧٦	اقرا عطار ست مرات	٥٢
اقرا سمَح ست مرات	٧٧	اقرا تَاقَش ست مرات	٥٣
اقرا سامرح ست مرات	٧٨	اقرا ثقّاش ست مرات	0 £
اقرا عَرَّف ست مرات	٧٩	اقرا دُكر ست مرات	٥٥
اقرا عرَّاف ست مرات	۸۰	اقرا دُكَّر ست مرات	٥٦
		اقرا زاول ست مرات	٥٧
		اقرا زواًل ست مرات	٥٨
		اقرا حَشْدَ ست مرات	٥٩
		اقرا حَشَّد ست مرات	7,
		اقرا شَعَل ست مرات	٦١
		اقرا شاعل ست مرات	٦٢
		اقرا حلَّق ست مرات	٦٣
		اقرا حَلاَق ست مرات	٦٤
		اقرا عاورد ست مرات	70
		اقرا عَوَّاد ست مرات	7
		اقرا رَجَع ست مرات	٦٧
		اقرا رَجَع ست مرات	٦٨
		اقرا رَجَع ست مرات	٦ ٩
		اقرا رَاجَع ست مرات	٧٠

### Appendix-B

# The Computer Software Package Used Written by Mark Huckvale / 2002 Dept. of Phonetics and Linguistics /UCL

The Speech Filing System is a program which is manipulated to carry out the experimental part of the present research. It is multifunction software whose design facilitates analyzing certain acoustic parameters, such as frequency, duration, intensity... etc. It also supports creating various graphs, such as wide-band and narrow-band spectrograms, waveforms and intensity tracings required for achieving an acoustic analysis. The sections below present the main steps to be followed on the part of the SFS user.

#### 1. Introduction

SFSWin is a shell program that runs on Windows PCs only. It allows the operation of most of the SFS programs by menu selection and dialogues rather than through the command-line. Although SFSWin is a native Windows program, the remaining parts of SFS continue in their 'portable' format: using device independent graphics and supporting Unix and MSDOS as well as Windows.

#### 2. Hardware and Software Installation

To make the best use of SFSWin requires knowledge of the audio configuration of your computer. Before you start, check:

- 1. that the audio output from the computer is connected to speakers or headphones.
- 2. that the microphone-level audio input is connected to a working microphone (if used)
- 3. that the line-level audio input is connected to your tape recorder (if used)

- 4. that the audio input devices are selected and set to a proper recording volume (in the Volume Controls application)
- 5. that the audio output device is selected and set to a proper replay volume (in the Volume Controls application)

You can check recording levels on the record dialogue in SFSWin, using the 'Test Levels' button. All volume levels are set outside SFSWin, using the Volume Control application, which can be found on the Start menu: usually under Programs/Accessories/Multimedia/Volume Control.

SFSWin uses the 'Hypertext Help' format for its documentation and help files. Although this is the new standard format help for Windows computers, many machines do not have this installed. If the SFSWin menu command 'Help/Help Contents' does not display the help file, you will need to run the HHUPD.EXE file included with the SFS installation. Microsoft Internet Explorer version 3 or later is also required.

#### 3. Getting Started

Start SFSWin. You will see an empty SFS file displayed called 'Unknown1'. We will **create a signal** and store it in this file, then replay it.

- Select menu option Tools/Generate/Test signals. A dialogue box will appear which asks you what kind of signal you would like to generate.
- Click on 'Generate Sinewave' so that a tick appears.
- Set the frequency to 500 (Hertz)
- Click on 'OK'

You will now see an entry in the SFSWin display for the file Unknown1 that says: SPEECH 1.01 10000 testsig(type=sine,freq=500)That is: an item of type SPEECH, numbered 1.01, consisting of 10,000 samples generated by the testsig program. If you click on the replay button, this tone should be replayed. If it doesn't, try replaying from some other application to see if the audio connections

are OK and that the output volume is set loud enough. Let's **generate a second tone**. This time, set the frequency to 1000Hz. You should see two lines in the display:

```
SPEECH 1.01 10000 testsig(type=sine,freq=500)
SPEECH 1.02 10000 testsig(type=sine,freq=1000)
```

You can see that this new item has different parameters listed in the processing history text. If you click on the replay button, you should hear that it is the original tone that is replayed, not the new one. You can **control which item is replayed** by using the little check boxes to left of the items on the list. Start by leaving the upper box alone and ticking the second one. The replay button should now replay the second tone - it has a higher pitch. Now tick the first only and replay, now tick both and replay. The replay button replays all speech items that are ticked, or the first speech item if none are ticked.

To **display** our tones, click on the 'Display all items' button on the toolbar - it is the one just to the left of the question mark button. A new window should open with the graphs of both waveforms. To replay the top waveform, click the left button of the mouse in the y-axis box to the left of the top waveform and press the 'space' key. To replay the lower waveform, click the left button of the mouse in the y-axis box to the left of the lower waveform and press the 'space' key.

To zoom in to a small region of the display, click the left mouse button in the centre of the screen - a vertical cursor will appear at that point. Now position the mouse about 1cm to the right and click the right mouse button - a second vertical cursor will appear. Now click on the menu option View/Zoom In - the display will be redrawn to show the region between the cursors. It should be much more obvious that the lower tone is twice the frequency (i.e. each cyle is half the period) of the upper tone. To zoom back out again select the menu option View/Zoom Out. The zoom-in and zoom-out commands are also available as the down and up

arrows on the toolbar. For now, quit this program by selecting menu option File/Exit.

Back in SFSWin, you can **choose which items are displayed** by putting tick marks against them and using the 'Display checked items' button on the toolbar. Try this by checking the first item only and clicking on 'Display checked items' - you should see a display of only the first waveform. Now reverse it by checking the second waveform only then displaying. Finally, we will **save the contents** of this file for use later on. From the SFSWin display, select the menu option "File/Save As". Now find a suitable directory and give the file a suitable name, such as "test.sfs". You can now exit SFSWin.

#### 4. Recording

Start SFSWin and click on the record button in the toolbar. This dialogue box should be displayed. With your microphone connected and switched on, click on 'Test Levels'. You should see the peak level meter change in position as you make noises into the microphone. You should use the Volume Control application to set the sensitivity of the audio input. Ideally, when you speak the peak level meter should not reach the right hand side of the display, although there should be significant movement of the level meter, at least up to half-way on some parts of the recording. When you have set the levels appropriately, click on Stop. To record a signal click on Record to start and Stop to stop. You can play back what has just been recorded by clicking on the Play button. Once you are happy with the recording, click the Done button. To change the recording quality you can change the sampling rate. The default rate of 16000 samples/second is usually fine for most speech signal work. However some PCs do not support this sampling rate. If the signal seems to be replaying at the wrong speed, try rates of 11025 or 22050 samples/sec; these are more widespread. Rates higher than 22050 are rarely necessary for speech. SFSWin will also record a stereo signal into two separate speech items.

#### 5. Basic Signal Processing

Record a short phrase or load the Windows file "chimes.wav" (select File/Open and locate the file in the Media sub directory of the Windows system directory; select the 'Speech' and 'Link to File' options in the Open Audio File dialogue box). To perform some simple filtering select the option menu Tools/Speech//Process/Filtering/Low-pass filter. appears A dialogue box requesting the settings to use. Leave the cut-off frequency set at 1000Hz and the number of sections at 4. Click OK and a second speech item will appear in the file. Put a check mark against both items and click on replay. You will hear the original and the low-pass filtered version. To do high-pass filtering first put a check mark by the original unfiltered speech item only. Then select menu option Tools/Speech/Process/Filtering/High-pass filter. Leave the cut-off frequency at 1000Hz and the number of sections at 4. Click OK. A third speech item is now present in the file. Check all the items and replay them. The reason we needed to check the first item before applying the high-pass filter is that by default most SFS programs operate upon the last item of the appropriate type in the file. Thus if we had left both items unchecked, we would have high-pass filtered the low-pass filtered signal! We can show the **processing history tree** by selecting menu option Tools/Display tree. If you have selected the items correctly for filtering, the result should look like this: Here you can see graphically that item 1.01 (shown as SP.01) has been processed into two new items: 1.02 (the low-pass) and 1.03 (the highpass).

#### 6. Spectrum and Spectrogram Display

Using the file containing the three signals we built in the last section, we can **display spectral cross sections** of the various versions. Start by checking the first item only. Select menu option Tools/Speech/Display/Cross section. You should see a display in two parts, with the original waveform at the top and two graphs below. To calculate and display a spectrum of a short section of waveform, place two

cursors on the waveform using the left and right mouse buttons. This region is then analyzed and the spectra displayed in the bottom window. The filter response graph is based on an LPC analysis of the signal, useful for finding formant values from vowel sounds. Quit this program and bring up spectral cross-sections of each of the other two items in the file in turn. Do this by checking the selected item and picking the Cross section menu option. Confirm that the filtering has done its job! You can **display spectrograms** of the various signals very simply. Leave all items unchecked for now. Choose menu option Tools/Speech/Edit, this will bring up a dialogue box in which the option "Display speech as waveform" will be checked. Remove this check mark and check "Display speech as wide-band spectrogram" instead. Click OK. A display containing the three signals analyzed in the form of a wide-band spectrogram will appear. You can use the cursors for zoom and replay as before. You can display **cross sections and spectrograms** simultaneously with menu option "Tools/Speech/Display/Cross section (spectrogram)".

#### 7. Item Deletion

For the next part of our tour, we show how deletion works. For this we will process the high-pass filtered signal (1.03) one more time and then delete it. Check item 1.03 only and select menu option Tools/Speech/Process/Filtering/Low-pass filter. Change the cut-off frequency to 2500Hz and click OK (earlier we had high-pass filtered at 1000Hz, so the result will be a band-pass between 1000 and 2500). A fourth speech item will appear. Now put a check mark against item 1.03 again and select menu option Item/Delete. A message box will ask if you are sure, reply OK. The display will now look like this: Note that although item 1.03 remains in the list, it no longer has a check box next to it and it cannot be selected nor displayed. It really has been deleted although a record of it is kept in the file. The tree display shows what has happened: The diagonal line through item 1.03 (SP.03) is an indication that the data associated with this item has been removed, although its history is maintained so that we are able to determine the complete processing history of item 1.04. If we delete item 1.04, you will find that this record (of 1.03) also gets deleted.

## 8. Other Data Types

As well as SPEECH items, many other types of data may be stored in SFS files. The following demonstrates some of these: the Fundamental frequency item (FX), the Coefficient item (CO) and the display item (DI). To calculate a fundamental frequency track, start with a file containing just a speech signal (or 'chimes.wav'). Then put a check mark next to the item and select menu option "Tools/Speech/Analysis/Fundamental frequency track". A window will appear while the processing is being performed, and once complete a new item (4.01) will appear in the file, of type FX ("frequency of excitation"). If you now display the file, you will see both a waveform and the fundamental frequency track.

We now calculate a set of **spectral coefficients** from our signal file. We choose to use a 19-channel filterbank analysis which gives us 19 frequency values between 0 and 5000Hz every 10ms. Checkmark the original speech signal and "Tools/Speech/Analysis/Filterbank/19-channel auditory menu option filterbank". After a brief amount of processing, a new item (10.01) of type COEFF will appear in the file. The display of the spectral coefficients item is not very clear. To convert coefficients to a greyscale display, select menu option "Tools/Coefficients/Make grey scale version", and accept the default parameters. A new item (9.01) of type DISPLAY will appear in the file. Display the speech waveform and the display item by checking them both and choosing "Display checked items" from the toolbar. Finally we will attempt to recreate the speech signal from the spectral coefficients through the use of a 19-channel filterbank synthesizer. Select the FX item and the CO item and choose menu option "Tools/Coefficients/19-channel synthesis". A new speech item will be created, which will sound a bit like the original signal(!). Display the SP, FX and DI items to get this: You should by now be able to interpret this processing history tree: It shows how the coefficient data, calculated from the original speech signal, was used to produce both a grey-level display and (along with the Fx) a new synthetic speech signal.

# Appendix-C

### THE INTERNATIONAL PHONETIC ALPHABET (revised to 1993)

#### CONSONANTS (PULMONIC)

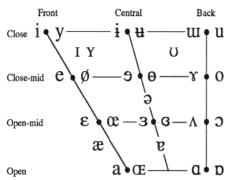
	Bila	bial	Labio	dental	De	ntal	Alve	olar	Postal	veolar	Retr	oflex	Pala	atal	Ve	lar	Uvu	ılar	Phary	ngeal	Gl	ottal
Plosive	p	b					t	d			t	þ	С	f	k	g	q	G			3	
Nasal		m		ŋ				n				η		ŋ		ŋ		N				
Trill		В						r										R				
Tap or Flap								ſ				τ										
Fricative	ф	β	f	V	θ	ð	s	Z	ſ	3	ş	ą	ç	j	X	Y	χ	R	ħ	ſ	h	ĥ
Lateral fricative							1	ß														
Approximant				υ				I				Į		j		щ						
Lateral approximant								1				l		λ		L						

Where symbols appear in pairs, the one to the right represents a voiced consonant. Shaded areas denote articulations judged impossible.

#### CONSONANTS (NON-PULMONIC)

Cli	cks	Voi	ced implosives	Ejectives				
0	Bilabial	6	Bilabial	,	as in:			
	Dental	ď	Dental/alveolar	p'	Bilabial			
!	(Post)alveolar	t	Palatal	ť	Dental/alveolar			
+	Palatoalveolar	g	Velar	k'	Velar			
	Alveolar lateral	G	Uvular	s'	Alveolar fricative			

#### VOWELS



Where symbols appear in pairs, the one to the right represents a rounded vowel.

## OTHER SYMBOLS

M Voiceless labial-velar fricative

W Voiced labial-velar approximant

U Voiced labial-palatal approximant

H Voiceless epiglottal fricative

Yoiced epiglottal fricative

Epiglottal plosive

C Z Alveolo-palatal fricatives

Alveolar lateral flap

f Simultaneous ∫ and X Affricates and double articulations can be represented by two symbols joined by a tie bar if

SUPRASEGMENTAL	S
----------------	---

Half-long

Minor (foot) group

Linking (absence of a break)

#### TONES & WORD ACCENTS CONTOUR Secondary stress founə'tıʃən € or T Extra ě or A Rising eı ⊢ High ĕ Syllable break li.ækt \_ Extra Rising-falling Major (intonation) group ↓ Downstep Global rise ↑ Upstep

Global fall

	D	IACRITICS	I	Diacritics may be placed above a symbol with a descender, e.g. $\mathring{\mathbf{J}}$
	٥	Voiceless n	ģ	Breathy voiced b a Dental t d
	~	Voiced §	ţ	_ Creaky voiced b a L Apical t d
	h	$_{\text{Aspirated}} \ t^h$	$d^{h}$	_ Linguolabial t d Laminal t d
	,	More rounded	ş	$^{w}$ Labialized $t^{w}$ $d^{w}$ $^{\sim}$ Nasalized $\tilde{e}$
	Ç	Less rounded	ç	$^{j}$ Palatalized $t^{j}$ $d^{j}$ $^{n}$ Nasal release $d^{n}$
	+	Advanced	ų	$_{\text{Velarized}}^{\text{Y}}$ $t^{\text{Y}}$ $d^{\text{Y}}$ $^{\text{I}}$ $^{\text{Lateral release}}$ $d^{\text{I}}$
		Retracted	<u>i</u>	Pharyngealized t d No audible release d
S	••	Centralized	ë	<ul> <li>Velarized or pharyngealized 1</li> </ul>
	×	Mid-centralized	ě	Raised C (I = voiced alveolar fricative)
	ı	Syllabic	ļ	Lowered Ç ( = voiced bilabial approximant)
	^	Non-syllabic	ě	Advanced Tongue Root C
	·	Rhoticity	Э٠	Retracted Tongue Root 🧧

# **BIBLIOGRAPHY**

- Abboud, P. F., Abdel-Malek, Z. N., Bezirgan, N. A., Erwin, W. M., Khouri, M. A., McCarus, E. N., Rammuny, R. M., and Saad, G. N. (1983).
  Elementary Modern Standard Arabic, Part I, edited by Abboud, P. F., and McCarus, E. N. Cambridge: Cambridge University Press.
- Abdul-Tawwab, R. (1973). Fușool Fi Fiqh Al-Arabiyah. "Chapters of Arabic Philology". (1st ed.). Cairo: Dar Al-Turaath Library.
- **Abercrombie, D. (1965).** *Studies in Phonetics and Linguistics.* London: Oxford University Press.
- **Abercrombie, D.** ( **1967** ). *Elements of General Phonetics*. Edinburgh: Edinburgh University Press.
- Abu Sharifah, A., Ilayyan, H. A., Al-Sarisi, O., and Adas, M. A. (1990).

  \*Diraasaat Fi Al-Lughah Al-Arabiyah. "Studies on Arabic". (2<sup>nd</sup> ed.).

  \*Amman: Dar Al-Fikr Publisher.
- Al-Ani, S. H. (1978). *Readings in Arabic Linguistics*. Indiana: Indiana University Linguistics Club.
- Ali, A. M. (1987). A Linguistic Study of the Development of Scientific

  Vocabulary in Standard Arabic. London: Kegan Paul International.
- Allerton, D. J. (1979). Essentials of Grammatical Theory: A Consensus View of Syntax and Morphology. London: Routeledge and Kegan Paul Ltd.

- Al-Mahfoudh, B. (2000). Speaking Rate in Iraqi Arabic and Standard British

  English: A Contrastive Study. Unpublished M.A. Thesis, University
  of Basrah.
- Al-Mubarak, M. (1970). Al-Nu soo s Al-Lughawiyah: Nu soo s Min Kitaabay

  Al-Kha sa`i s Wa Al-Muzhir Fi Al-Uloom. "Linguistic Texts: Some

  Texts Cited from Al-Kha sa`i s and Al-Muzhir Fi Al-Uloom". Beirut:

  Dar Al-FikrPublisher.
- Al-Qazzaz, A. J. (1981). Al-Diraasaat Al-Lughawyiah Fi Al-Iraq Fi An-nişf Al-Awal Min Al-Qarn Al-`Ishreen. "Linguistic Studies in Iraq in the First Half of the 20<sup>th</sup> Century". Baghdad: Dar Al-Rasheed Publisher.
- Al-Sa`araan, M. (1962). Ilm Al-Lughah: Muqaddimah Lilqaari` Al-Arabi.

  "Linguistics: An Introduction to the Arab Reader". Cairo: Dar
  Al-Ma`aarif.
- Al-Sheikhli, K. A. (1991). *Impact of Translation on Modern Standard Arabic*.

  Unpublished M.A. Thesis, Al-Mustansiriya University.
- Al-Zaidi, Y. G. (1987). Fiqh Al-Lughah Al-Arabiyah. "Arabic Philology".

  Mousl: Dar Al-Kutub Press.
- **Anis, I.** (1961). *Al-Aşwaat Al-Lughawiyah* . "*Linguistic Sounds*". (5<sup>th</sup> ed.). Cairo: Dar Al-Nahdhah Al-Arabiyah.
- **Anis, I.** (1966-1967). *Turuq Tanmiyat Al-Al-Fadh*. "Developing Techniques of Vocabularies" Cairo : Al-Nahdhah Al-Jadida Press.

- Behne, D., Czigler, P. E., and Sullivan, K. P. H. (1998). "Perceived Swedish Vowel Quantity: Effects of Postvocalic Consonant Duration", pp. 1-4.

  Available: http://www.shlrc.mg.edu.au./proceedings/icpl98/pdf/scan/SL98/031.pdf.
- **Belasco, S.** (1953). "The Influence of Force of Articulation of Consonants on Vowel Duration", *Journal of Acoustical Society of America*, vol. 25, pp. 1015-1016.
- Birkeland, H. (1954). Stress Patterns in Arabic. Oslo: Jacob Dybwad.
- Botinis, A., Banner, R., Fourakis, M., and Pagoni-Tetlow, S. (2002). "Prosodic Effects and Crosslinguistic Segmental Durations", pp. 77-80.

Available: <a href="http://www.speech.kth.se/qpsrltmh/2002/02-44-077-080.pdf">http://www.speech.kth.se/qpsrltmh/2002/02-44-077-080.pdf</a>.

**Braunschweiler, N. (1997).** "Integrated Cues of Voicing and Vowel Length in German: A Production Study", *Language & Speech*, vol. 40, no. 4, pp. 353-376. (Abstract).

Available: <a href="http://www.ling.ed.ac.uk/~lgsp/braunschweiler.html">http://www.ling.ed.ac.uk/~lgsp/braunschweiler.html</a>.

- Brosnahan, L. F., and Malmberg, B. (1970). *Introduction to Phonetics*.

  Cambridge: Cambridge University Press.
- Byrd, D., and Tan, C. C. (1996). "Saying Consonant Clusters Quickly", *Journal of Phonetics*, Academic Press Ltd. no. 24, pp. 263-282.

Available: <a href="http://www.rcf.usc.edu/~dbyrd/Byrd-Tan-Jphone-1996.pdf">http://www.rcf.usc.edu/~dbyrd/Byrd-Tan-Jphone-1996.pdf</a>.

- Catford, J. C. (1988). A Practical Introduction to Phonetics. (1st ed.). Oxford: Clarendon Press.
- **Chen, M.** (1970). "Vowel Length Variation as a Function of the Voicing of the Consonant Environment", *Phonetica*, vol. 22, pp. 129-159.

- Chung, H., Kim, K., and Huckvale, M. (2003). "Consonantal and Prosodic Influences on Korean Vowel Duration", pp. 1-4.
- Available: <a href="http://www.phon.ucl.ac.uk/home/hchung/paper/co63.pdf">http://www.phon.ucl.ac.uk/home/hchung/paper/co63.pdf</a>.
- Cohen, L. (1954). Statistical Methods for Social Scientists: An Introduction.

  Englewood Cliffs: Prentice-Hall, Inc.
- Cowan, W. (1958). *An Introduction to Modern Literary Arabic*. London: Cambridge University Press.
- Crystal, D. (1997). A Dictionary of Linguistics and Phonetics. (4<sup>th</sup> ed.). Oxford: Blackwell Publishers Ltd.
- de Jong, K. J. (2001). "Effects of Syllable Affiliation and Consonant Voicing on Temporal Adjustment in a Repetitive Speech-Production Task", *Journal* of Speech, Language, and Hearing Research, American Speech-Language-Hearing Association, vol. 44, pp. 826-840.
- Available: <a href="http://www.asha.org/NR/rdonlyers/BF266610-4BBB-484C-BE6E-A54E-4A9/2BA710/6302-1.pdf">http://www.asha.org/NR/rdonlyers/BF266610-4BBB-484C-BE6E-A54E-4A9/2BA710/6302-1.pdf</a>.
- **de Lacy, P. (1998).** "The Effect of Consonant Clusters on Vowel Duration in English", pp. 1-20.
- Available: http://www.cus.cam.ac.uk/~Pvd22/Docs/Papers/delacy-effectcc.pdf.
- **Delattre, P. (1962).** "Some Factors on Vowel Duration and Their Cross- Linguistic Validity", *Journal of Acoustical Society of America*, vol. 34, pp. 1141-1143.
- Faluschi, S., and Di Benedetto, M. (2001). "Acoustic Analysis of Singleton and Geminate Affricates", *The European Student Journal of Language and Speech*, pp. 1-16.

Available: <a href="http://www.essex.ac.uk./web-sls/papers/01-01/submission.html">http://www.essex.ac.uk./web-sls/papers/01-01/submission.html</a>.

- **Ferguson, C. A. (1957).** "Two Problems in Arabic Phonology", *Word*, vol. 13 pp. 460-478.
- **Fintoft, K. (1961).** "The Duration of Some Norwegian Speech Sounds", *Phonetica*, vol. 7, pp. 19-39.
- **Flemming, E. (1997).** "Phonetic Optimization: Compromise in Speech Production", pp. 1-16.

Available: <a href="http://www.stanford.edu/~flemming/paper/ot-html">http://www.stanford.edu/~flemming/paper/ot-html</a>.

- Frayha, A. (1953). Essentials of Arabic: A Manual for Teaching Classical Arabic and Colloquial Arabic. Beirut: Khayat's College Book Co-operative.
- Fujisaki, H., Nakamura, K., and Imoto, T. (1975). "Auditory Perception of Duration of Speech and Non-Speech Stimuli", *Auditory Analysis and Perception of Speech*, edited by Fant, G. and Thatam, M.A.A. London: Academic Press Ltd., pp. 197-219.
- Gairdner, W. H. T. (1935). "The Arab Phoneticians on the Consonants and Vowels", *Readings in Arabic Linguistics*, edited by Al-Ani, S.H. (1978). Indiana: Indiana University Linguistics Club, pp. 187-202
- Gatta, B. I. (1988). A Contrastive Study of the Intonational Patterns of

  Questions in Standard English and Modern Standard Arabic.

  Unpublished M.A.Thesis, University of Basrah.
- Ghalib, G. B. M. (1977). *The Intonation of Colloquial Iraqi Spoken Arabic*. Unpublished M. Phil. Thesis, University of Leeds.

- Ghalib, G. B. M. (1984). An Experimental Study of Consonant Gemination in Iraqi Colloquial Arabic. Unpublished Ph.D. Thesis, University of Leeds.
- Gimson, A. C. (1980). *An Introduction to the Pronunciation of English*. (3<sup>rd</sup> ed.). London: Edward Arnold Ltd.
- Gimson, A. C. (1989). *An Introduction to the Pronunciation of English*. (4<sup>th</sup> ed). London: Edward Arnold Ltd.
- Giovanardi, M. and Di Benedetto, M. (1998). "Acoustic Analysis of Singleton and Geminate Fricatives in Italian", *The European Student Journal of Language and Speech*, pp. 1-15.

Available: http://www.essex.ac.uk./web-sls/Paper/98-01/98-01.html.

Gordon, M., Munro, P., and Ladefoged, P. (1997). "Some Phonetic Structures Of Chickasaw", *UCLA Working Papers in Phonetics*, 95, pp. 41-67, (electronically pp. 1-28).

Available: <a href="http://www.linguistics.uscb.edu/faculty/gordon/somephon.pdf">http://www.linguistics.uscb.edu/faculty/gordon/somephon.pdf</a>.

Hagiwara, R. (2004). "Monthly Mystery Spectrogram", pp. 1-11.

Available: <a href="http://home.cc.unantioba.ca/~robh/how-to.html">http://home.cc.unantioba.ca/~robh/how-to.html</a>.

**Hajeck, J.** (2003). "Phonological Length and Phonetic Duration in Bolonese: Are They Related?", pp. 1-6.

Available: http://www.french-italian-unimelb.edu.au/research/jhbol2.pdf.

Han, M. S. (1965). "The Feature of Duration in Japanese", *Journal of Phonetic Society of Japanese*, Study and Sound, vol. 10, pp. 65-80.

Hansen, B. B. (2004). "Production of Persian Geminate Stops: Effects of Varying Speaking Rate", *Proceedings of the 2003 Texas Linguistics Society Conference*, edited by Agwuele, A., Warren, W., and Park, S. Somerville, MA: Cascadilla Proceedings Project, pp. 86-95.

Available: <a href="http://lingref.com/cpp/tls/2003/paper/070.pdf">http://lingref.com/cpp/tls/2003/paper/070.pdf</a>.

- Harrel, R. S. (1957). *The Phonology of Colloquial Egyptian Arabic*. New York: American Council of Learned Societies.
- Hassan, Z. M. (1981). An Experimental Study of Vowel Duration in Iraqi Spoken Arabic. Unpublished Ph.D.Theis, University of Leeds.
- Hassan, Z. M. (2002). "Gemination in Swedish & Arabic with a Particular Reference to the Preceding Vowel Duration: An Instrumental & Comparative Approach", TMLL-QPSR Fonetik, vol. 44, pp. 81-84.

Available: <a href="http://www.speech.kth.se/qpsr/tmn/2002/02-44-081-084.pdf">http://www.speech.kth.se/qpsr/tmn/2002/02-44-081-084.pdf</a>.

**Hassan, Z. M.** (2003). "Temporal Compensation Between Vowel and Consonant Duration in Swedish & Arabic in Sequences of CV:C & CVC: and the Word Overall Duration", *Phonum*, 9, pp. 45-48.

Available: <a href="http://www.ling.uma.se/fonetik2003.pdf">http://www.ling.uma.se/fonetik2003.pdf</a>

- Hays, S. (1970). An Outline of Statistics. (8th ed.). London: Longman Group Ltd.
- **Heffner, R-M. S. (1950).** *General Phonetics.* Wisconsin: The University of Wisconsin Press.
- Hewlett, N., Matthews, B., and Scobbie, J. M. (1999). "Vowel Duration in Scottish English Speaking Children", *ICPh99 San Francisco*, pp. 2157- 2160.

Available: <a href="http://sls.qmuc.ac.uk/pubs/hewl991.pdf">http://sls.qmuc.ac.uk/pubs/hewl991.pdf</a>.

- Hijazi, M. F. (1978). *Madkhal Ila Ilm Al-Lugah*. "A Preface to Linguistics". Cairo: Dar Al-Thaqaafah Press.
- **Hill, A. B. (1984).** *A Short Textbook of Medical Statistics.* (11<sup>th</sup> ed.). London: Edward Arnold.
- **Hodge, C. T. (1969).** "Morphology and Syntax", *Linguistics*, edited by Hill, A. A. Washington: Voice of America Forum Lectures, pp. 33-42.
- House, A. S., and Fairbanks, G. (1953). "The Influence of Consonant Environment Upon the Secondary Acoustical Characteristics of Vowels", *Journal of Acoustical Society of America*, vol. 25, pp. 105-113.
- House, A. S. (1961). "On Vowel Duration in English", *Journal of Acoustical Society of America*, vol. 33, pp. 1174-1178.
- **Huckvale, M. (2002).** "Speech Filing System Version 1.33" (Computer Software). Available: <a href="http://www.phon.ucl.ac.ul./resource/sfs">http://www.phon.ucl.ac.ul./resource/sfs</a>.
- Hussein, M. (1960). *Diraasaat Fi Al-Arabiyah Wa Taarikhiha*. "Studies on Arabic and Its History". (2<sup>nd</sup> ed.), edited by Al-Tunisi, A. Demuscus: Dar Al-Fath Library.
- Ingram, J. A. (1977). *Elementary Statistics*. California: Cumming Publishing Company, Inc.
- Jespersen, O. (1961). A Modern English Grammar: On Historical Principles,

  Part VI Morphology. Oxford: Alden & Mow Bray Ltd.
- **Jones, D.** (1956). *The Pronunciation of English*. (4<sup>th</sup> ed.). Cambridge: Cambridge University Press.

- **Jones, D. (1967).** *The Phoneme: Its Nature and Use.* (3<sup>rd</sup> ed.). Cambridge: Cambridge University Press.
- Joos, M. (1948). Acoustic Phonetics. Baltimore: Supplement to Language.
- Ken`aan, S. A. (1977). A Contrastive Study of Standard English and Baghdad Arabic Word Stress Patterns. Unpublished M.A. Thesis, University of Baghdad.
- Kenstowicz, M. J., and Pyle, C. (1973). "On the Phonological Integrity of Geminate Clusters", *Issues in Phonological Theory: Proceedings of the Urban Conference on Phonology*, edited by Kenstowicz, M. and Kissebirth, C. W. Mouton: The Hague, pp. 27-43.
- **Kiparsky, P. (1999).** "Syllables and Moras in Arabic", pp. 1-31. Available: <a href="http://www.stanford.ed./~kiparsky/papers.syll.pdf">http://www.stanford.ed./~kiparsky/papers.syll.pdf</a>.
- Klatt, D. H. (1974). "The Duration of [s] in English Words", *Journal of Speech* and *Hearing Reseach*, vol. 17, pp. 51-63.
- **Klatt, D. H.** (1976). "Linguistic Uses of Segmental Duration in English: Acoustic and Perceptual Evidence", *Journal of Acoustical Society of America*, 59, pp. 1208-1221.
- Kuijpers, C. T.L. (1993). Temporal Coordination in Speech Development:
   A Study on Voicing Contrast and Assimilation of Voice.
   Unpublished Ph.D.Thesis, University of Amsterdam. Amsterdam:
   Proceedings of the Institute of Phonetic Sciences. (Summary).

Available: http://fonsg3.let.uva.nl/Proceedings/Proceedings\_17\_Summaries.html.

- Ladefoged, P. (1975). A Course in Phonetics. New York: Harcourt Brace Jovanovich, Inc.
- Liberman, A. M., Cooper, F. S., Shankweiler, D. P., and Studdert-Kennedy, M. (1967). "Perception of the Speech Code", *Psychological Review*, vol. 74, pp. 431-461.
- Lindsay, J. M. (1997). Techniques in Human Geography. London: Routledge.
- Maddieson, I. (1985). "Phonetic Cues to Syllabification", *Phonetic Linguistics:Essays in Honour of Peter Ladefoged*, edited by Fromkin, V. A.Academic Press, Inc., pp. 203-221
- Malécot, A. (1970). "The Lenis-Fortis Opposition: Its Psychological Parameter", *Journal of Acoustical Society of America*, vol. 47, pp. 1588-1592.
- Malmberg, B. (1963). *Phonetics*. New York: Dover Publishers, Inc.
- Mattie, M., and Di Benedetto, M. (2000). "Acoustic Analysis of Singleton and Geminate Nasals in Italian", *The European Student Journal of Language and Speech*, pp. 1-14.

Available: <a href="http://www.essex.ac.uk/web-sls/papers/00-02/00-02.html">http://www.essex.ac.uk/web-sls/papers/00-02/00-02.html</a>.

- McKay, G. R. (1980). "Medial Stop Gemination in Rembarrnga: A Spectrographic Study", *Journal of Phonetics*, vol. 8, pp. 343-352.
- Mitchel, T. F. (1993). Pronouncing Arabic, vol. 2. Oxford: Clarendon Press.
- Morrison, G. R. (2002). Effects of L1 Duration Experience on Japanese and Spanish Learners' Perception of English High Front Vowels. M.A. Thesis, Simon Fraser University.

Available: <a href="http://www.ualberta.ca/~gsm2/Morrison\_2002\_MA\_Thesis.pdf">http://www.ualberta.ca/~gsm2/Morrison\_2002\_MA\_Thesis.pdf</a>.

Morton, K. (1984). Experimental Phonology and Phonetics.

Available: <a href="http://www.essex.ac.uk/speech/pubs/books/exp-phon-phon/Exp-phon">http://www.essex.ac.uk/speech/pubs/books/exp-phon-phon/Exp-phon.</a>
<a href="http://www.essex.ac.uk/speech/pubs/books/exp-phon-phon/Exp-phon">http://www.essex.ac.uk/speech/pubs/books/exp-phon-phon/Exp-phon.</a>

**Nagai, K** (1996). "Compensatory Lengthening by British Learners of Japanese", pp. 1-10.

Available: <a href="http://www.tsuyama-ct.ac.jp/kats/papaers/kn4/kn4.html">http://www.tsuyama-ct.ac.jp/kats/papaers/kn4/kn4.html</a>.

Nasr, R. T. (1960). "Phonemic Length in Lebanese Arabic", *Phonetica*, vol. 5, pp. 209-211.

Nasr, R. T. (1967). The Structure of Arabic: From Sound to Sentence. Beirut: Librairie De Liban.

Newman, D. L., and Verhoeven, J. (2002). "Frequency Analysis of Arabic Vowels in Connected Speech", pp. 77-86.

Available: <a href="http://www.uia.ac.be/apil/apil100/Arabic2.pdf">http://www.uia.ac.be/apil/apil100/Arabic2.pdf</a>.

Ng, Vincent (2004). "Segmenting Speech Acoustics and Predicting Facial Speech Movements", *UCLA Undergraduate Research Program in Electrical Engineering*, pp. 1-22.

Available: <a href="http://www.ugres.ee.ucla.edu/images/upload/V-Ng-Vincent-report.pdf">http://www.ugres.ee.ucla.edu/images/upload/V-Ng-Vincent-report.pdf</a>.

- **Nooteboom, S. G., and Slis, I. H. (1972).** "The Phonetic Feature of Vowel Length in Dutch", *Language and Speech*, vol. 15, pp. 301-316.
- **Obrecht, D. H.** (1965). "Three Experiments in the Perception of Geminate Consonants in Arabic", *Language and Speech*, vol. 8, pp. 31-41.
- O'Connor, J. D. (1973). Phonetics. Harmondsworth: Penguin Books Ltd.

- Omar, A. M. (1976). Diraasat Al-Şawt Al-Lughawiy. "Study on the Linguistic Sound". Cairo: Alam Al-Kutub Press.
- Peterson, G. E., and Lehiste, I. (1960). "Duration of Syllable Nuclie in English", *Journal of Acoustical Society of America*, vol. 32, pp. 693-703.
- Pickett, J. M., and Decker, L. R. (1960). "Time Factors in Perception of a Double Consonant", *Language and Speech*, vol. 3, pp. 11-17.
- Port, R. F., Al-Ani, S., and Maeda, S. (1980). "Temporal Compensation and Universal Phonetics", *Phonetica*, vol. 37, pp. 235-252.
- **Port, R. F., and Leary, A. P. (2000).** "Speech Timing in Linguistics", pp. 1-31. Available: <a href="http://www.cs.indiana.edu/~port/pap/port-leary.2000.pdf">http://www.cs.indiana.edu/~port/pap/port-leary.2000.pdf</a>.
- **Raphael, L. J.** (1972). "Preceding Vowel Duration as a Cue to the Perception of the Voicing Characteristic of Word-Final Consonants in American English", *Journal of Acoustical Society of America*, vol. 51, no. 4, (part 2) pp. 1296-1303.
- Raphael, L. J., Dorman, M. F., and Liberman, A. M. (1980). "On Defining the Vowel Duration that Cues Voicing in Final Position", *Language and Speech*, vol. 23, pp. 297-307.
- Roach, P. (1983). *English Phonetics and Phonology: A Practical Course*. (1<sup>st</sup> ed.). Cambridge: Cambridge University Press.
- Roach, P. (1991). *English Phonetics and Phonology: A Practical Course*. (2<sup>nd</sup> ed.) Cambridge: Cambridge University Press.

Roach, P. (2002). A Little Encyclopedia of Phonetics.

Available: <a href="http://www.personal.rdg.ac.uk/~llsoach/encyc.pdf">http://www.personal.rdg.ac.uk/~llsoach/encyc.pdf</a>.

Robins, R. H. (1964). *General Linguistics: An Introductory Survey*. London: Longman Group Ltd.

Runyon, R. P., and Haber, A. (1976). Fundamentals of Behavioral Statistics. (3<sup>rd</sup> ed.). California: Addison-Wesley Publishing Company, Inc.

Scobbie, J. M., Turk, A. E., and Hewlett, N. (1999). "Morphemes, Phonetics and Lexical Items: The Case of the Scottish Vowel Length Rules", *ICPh99*San Francisco, pp. 1617-1620.

Available: <a href="http://sls.qmuc.ac.uk/pubs/scob99.pdf">http://sls.qmuc.ac.uk/pubs/scob99.pdf</a>.

Scully, C. (1975). "A Synthesizer Study of Aerodynamic Factors in Speech Segment Durations", *Progress in Speech Communication. Proceedings of Speech Communication Seminar, Stockholm*, 1974, edited by Fant, G. Stockholm: Wiley, vol. 2, pp. 227-234.

**Selouani, S. and Caelen, J. (2004).** "Spotting Arabic Phonetic Features Using Modular Connectionist Architectures and a Rule-Based System", pp. 1-5.

Available: <a href="http://clips.img.fr/geod/user/jean.caelen/publis\_fichiers/">http://clips.img.fr/geod/user/jean.caelen/publis\_fichiers/</a>
Reconnaissance Regles.pdf.

Siegel, S. (1956). *Nonparametric Statistics: For the Behavioural Sciences*.

Tokyo: McGrow-Hill Ko Ga Kusha, Ltd.

**Stetson, R. H. (1950).** *Motor Phonetics.* (2<sup>nd</sup> ed.). Amsterdam: North-Holland Publishing Company.

- **Thatcher, G. W. (1956).** *Arabic Grammar of the Written Language*. (5<sup>th</sup> ed.), Edited by Nahmad, H.M. London: Prey Lund, Humpheries & CO. Ltd.
- van Leyden, K. (2002). "The Relationship Between Vowel and Consonant Duration in Shetland Dialects", *Phonetica*, 59, pp. 1-19.

  Available: http://www.karger.com/journals/pho
- van Son, R. J. J. H., and van Santen, J. P. H. (1997). "Strong Interaction Between Factors Influencing Consonant Duration", pp. 1-8.

Available: http://fonsg3.letuva.nl/IFA-publications/Eurospeech97/A0456.html.

- Ward, I. C. (1972). *The Phonetics of English*. (5<sup>th</sup> ed.). Cambridge: W. Heffner & Sons Ltd.
- Yule, G. (1996). *The Study of Language*. (2<sup>nd</sup> ed.). Cambridge: Cambridge University Press.
- Zafeiri, S. (2002-2003). Investigation of Intrinsic Vowel Length in English Accents. M.Sc. Thesis, University of Edinburgh.
- Available: <a href="http://www.ling.ed.ac.uk/teaching/posrad/mscslp/archive/">http://www.ling.ed.ac.uk/teaching/posrad/mscslp/archive/</a> dissertations /2002-3/stavroula-zafeiri.pdf.
- **Zimmerman, S. A. and Sapon, S. M. (1958).** "Note on Vowel Duration Seen Cross-Linguistically", *Journal of Acoustical Society of America*, vol. 30, pp. 152-153.

## مستخلص

ان دراسة ظاهرة التعويض الزمني تساعد على كشف الانموذج الزمني الذي يميز الاصوات العربية مقارنة بمثيلاتها في اللغات الاخرى لقد أعد هذا البحث لاثبات وجود هذه الظاهرة في البنية المقطعية للغة العربية الحديثة، و قد قُسمت الدراسة الى خمسة فصول .

يتمخض الفصل الاول عن مقدمة للدراسة اعلاه بشكل عام اذ يسلط الضوء على المشكلة الرئيسة التي تتعلق باثبات وجود ظاهرة التعويض الزمني فضلاً عن ذلك فهو يعرض الفرضيات التي تم اختبارها عن طريق التجربة ، اضافة الى بيان مجال الدراسة و اهم اهدافها. والى جانب ذلك فهو يوضح الخطوط الرئيسة للاجراء التجريبي الذي تم اتباعه لتنفيذ الجزء التجريبي من البحث.

يتناول الفصل الثاني الخلفية النظرية و بشكل مختصر للنظام الصوتي في اللغة العربية الحديثة اذ انه يوجز نظام الاصوات ثم يوضح بعد ذلك انماط التركيب المقطعي و النبر الاساسية ، اضافة الى ذلك فهو يستعرض بشكل مختصر اهم طرق توليد الالفاظ في اللغة العربية الحديثة .

بينما يقدم الفصل الثالث مراجعة مفصلة للدراسات السابقة التي تناولت الامتداد الزمني لاصوات اللين (اصوات العلة) و الاصوات الصحيحة على حد سواء ، اضافة الى عرض اهم العوامل التي تؤثر على الامتداد الزمني لتلك الاصوات مع مراجعة لدراسات سابقة تناولت الظاهرة المعنية في اللغة العربية و بعض اللغات الاخرى.

يسلط الفصل الرابع الضوء على تصميم التجربة و الاجراء الذي تم تبنيه لاختيار و تصنيف الكلمات و طريقة التسجيل الصوتي اضافة الى ذلك فهو يقدم وصفا لبرنامج الحاسوب الذي تم استخدامه للحصول على التسجيلات الصوتية اللازمة لتطبيق تلك التجربة، كذلك فهويوضح الاجراء المتبع في استخراج القياسات الزمنية للاصوات المعنبة.

اما الفصل الخامس و الاخير فهو يعرض بشكل تفصيلي اهم النتائج و التحليل الاحصائي الذي أخضعت له بالاضافة الى التحليل المنتظم للنتائج، و هو كذلك يقدم الاستتاجات

النهائية التي تم استنباطها بالاعتماد على القياسات المستخرجة من الصور الطيفية الى جانب ذلك تقديمه لعدد من المقترحات التي قد تكون ذات فائدة للباحثين في المجال نفسه مستقبلا.

و اخر الامر ثلحق بالدر اسة ثلاثة ملاحق و قائمة بالمصادر التي تم اعتمادها لاكمال هذا البحث .

الباحثة

# جامعة البصرة



# دليل على وجود ظاهرة التعويض الزمني في بنية المقطع في اللغة العربية الحديثة: دراسة فيزياصوتية

رسالة مقدمة الى مجلس كلية الاداب في جامعة البصرة كجزء من متطلبات نيل درجة ماجستير آداب في علم اللغة التطبيقي

> اعدتها نجوى سالم يوسف

باشراف أ. د. غالب باقر محمد غالب

آب/٥٠٠٢