A Xeroradiographic, Ultrasonic, Laryngoscopic And Acoustic Study Of Pharyngeals And Emphatics In Arabic

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ABSTRACT

Arabic is mainly characterized by having two types of articulation mainly taking place in the pharyngeal cavity, the first is a primary articulation in producing the pharyngeal consonant the voiceless /ħ/ and the voiced /ʕ/ which are produced by making a constriction in the laryngopharyngeal cavity caused by retracting the root of the tongue and the attached epiglottis; the larynx is raised 10-13 mm, a constriction takes place in the laryngeal vestibule and the arytenoids move upwards. The second type is a secondary articulation, known as "emphasis"; this phonetic feature can move mainly from right to left and in some dialects from left to right as well, so any other consonant or vowel can become emphatic. The pharyngeal sounds and the emphatic feature are different, although they are produced in the same place of articulation.

1. INTRODUCTION

The aim of this work is mainly a quantitative investigation of the production of the feature of emphasis, and to a certain extent that of the pharyngeals /ħ/ and /ʕ/ to show differences between the pharyngeal sounds and the phonetic feature of emphasis. The techniques of Xeroradiography, Ultrasonic, Fiberobtic Laryngoscopy and Acoustics where that is relevant, will be used. The subjects run in the experiments are Jordanians . The author was run as the only subject in the ultrasonic and laryngoscopic experiments. The form of speech used is then completely based on Jordanian Arabic.

2. THE PHONETIC FEATURE OF EMPHASIS

The phenomenon of emphasis in Arabic has been the subject of many studies since the ancient Arab grammarians for more than one thousand years ago. They attributed emphasis "tafxim" to the coronal sounds /ð̲/, /t̲/, /d̲/, and /s̲/ and the uvulars /X/, /ʁ/ and /q̲/. These seven sounds have been described as "mustaʕliya" [+high] since in their production the body of the tongue is raised towards the soft palate (Sibawayhi 1889:406). The first four were described as "mutbaqa" [+cupped]; the rims of the tongue are raised to meet the hard palate making a hollow with the tongue, a sort of cup, the surface of the tongue being grooved. In the 19th and early 20th centuries, a number of orientalists treated emphasis through studying classical Arabic. The term emphasis itself was introduced by S. de Sacy (1810). Since early forties, many studies on emphasis in various Arabic dialects have been conducted, some used roentgenography, as Al-Ghazali (1977). Catford (1968) introduced the aryepiglottopharyngeal term and Esling (1966) examined in detail epiglottopharyngeal in terms of the function of the aryepiglottic sphincter mechanism. The terms pharyngealization,, velarization,, uvularization, F2 Drop and RTR have been used by some scholars to indicate the feature of emphasis.

3. XERORADIOGRAPHIC EXPERIMENT

This experiment was conducted at the Radiology department of the University Hospital, University of Wisconsin, with the help of Dr. S. Ewanowsky. Each of five native speakers of Jordanian Arabic was asked to produce a pair of words, one member of which contained the emphatic sound and the other member the non-emphatic counterpart. Life size Xeroradiograms were taken during the production of the relevant sounds. The aim was to get Xeroradiographic images of the configuration of the pharyngeal, oral and laryngeal cavities during the articulation of emphatic and their non-emphatic counterparts. The six pairs of words for which the xeroradiagrams were taken and used in this study and the subjects produced them are as follows:

Sb.	X	None -emphatic	X	Emphatic
1	1	/l/ in /walla/ "it's gone"	2	/l̲/ in /walla̲/ "I swear"
2	3	/ħ/ in /laħħam/ " he slaughtered"	4	/ħ̲/ in /raħħam̲/ "he cursed"
2	5	/ʕ/ in /naʕʕam/ "he ground sg."	6	/ʕ̲/ in /saʕʕab̲/ "made sg. difficult"
3	7	/s/ in /ħassab/ "he expected"	8	/s̲/ in /ħassab̲/ "got measles"
4	11	/ð/ in /ʕaððab/ "he tortured"	12	/ð̲/ in /ʕaððam̲/ "dignified"
5	13	/a:/ in /sa:b/ ""he left"	14	/a̲/ in /sa:b̲/ "he touched"

The pharyngeals /ħ/ and /ʕ/ were selected to find out how they can be emphatic and non emphatic (even they are

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articulated in the pharyngeal cavity). Fixed points in the head such as the vertebral column, the hypophysical fossa and the hard palate on the midsaggital plane were used as fixed reference points for the measurements. Transparencies were made for each of these original life size xeroradiagrams and tracings from the originals and transparencies were made on another blank transparent paper for each of the original pictures. Tracings of the emphatic and non-emphatic counterparts were superimposed on each other using the base of the skull and the bodies of the cervical vertebrae as fixed points in order to make a detailed contrastive study of the vocal tract configurations. Measurements, whenever possible were taken in mm by means of a transparent 1 mm graph paper from the tracings and checked against the originals when necessary.

The dimensions for which the measurements were made involve the following: the lips, the teeth, the tongue, the soft palate, the rear wall of the pharynx, the epiglottis, the hyoid bone the larynx and the mucus membrane. Not all the dimensions appear on every xeroradiogram because some of the locations did not appear and so were not measured.

Results:

The measurements taken show that:

1- The lips: the lips are slightly rounded and protruded. The distance between the upper lip and lower lip was (17 mm) for /l/ and (14 mm) for /l̲/. This dimension could only be measured for the lateral sound. The lower lip was found to be protruded, about (3mm) for /l̲/ than for /l/. The horizontal distance between the highest point on the lower central incisor and the most front point on the lower lip was(12 mm) for /l/ and (15 mm) for /l̲/.

2- The distance between the upper and lower jaws was found to be (3-4mm) for the emphatic sounds /l̲/, /ħ̲/ and /a/ greater than for the non-emphatic counterparts /l/, /ħ/,/a/.

3- The body of the tongue considerably is lowered (3-8 mm) and the root retracted towards the back wall of the pharynx (3-12mm) for the emphatic sounds compared with the non-emphatic counterparts.

4- The soft palate is stretched down during the production of the emphatic sounds (2-4 mm).

5- The tip of the uvula is lowered towards the dorsum of the tongue for the emphatic sounds (2-17mm).

6- The Velo-Glossal Cavity: A narrowing tends to take place between the dorsum of the tongue and the soft palate during the production of emphatic sounds due to the relaxing of the soft palate and tilting the uvula towards the retracted root of the tongue(0-10 mm).

7- The pharyngeal cavity: A narrowing takes place for the emphatics along the pharyngeal cavity and the maximum narrowing is almost always observed in the lower border of C_2 and C_3; Middle of C_2 (0-8mm), Lower border of C_2 (3-12 mm), Lower border of C_3 (2-11 mm), Lower border of C_4 (1-4 mm).

8- The narrowest width of the pharyngeal cavity: The narrowest part of the pharyngeal cavity during the production of non-emphatic sound is the area located between the lower border of C_2 and the upper border of C_4 and it is the same area where the maximum narrowing for emphatics takes place (1-9 mm); the least narrowing seems to be for the emphatic pharyngeals: /ħ̲/=1mm and /ʕ̲/=2mm

9- The mucus membrane of the posterior surface of the pharyngeal cavity: little and negligible change takes place in the thickness of the emphatic items compared to non-emphatic counterparts.

10- The epiglottis:

(a) The tip of the epiglottis is lowered during the production of emphatic sounds (1.5-5mm).

(b) Retraction for emphatic sounds is(2.5-10mm).

(c) Little change takes place in the distance between the tubercle and the arytenoid cartilage (1-2 mm). The change seems to take place in the upper edge of the epiglottis due to the retraction of the root of the tongue.

11- Level of the larynx: The larynx has been found to greatly elevate for emphatic /l̲/ and slightly elevate for emphatic /a̲:/. In the case of other emphatic sounds it is depressed. We would say that raising or lowering of the larynx is not a consistent gesture associated with the emphasis factors. Raising is a characteristic of pharyngeals.

4. ULTRASONIC EXPERIMENTS

Two of these experiments were conducted at the radiology department of the University Hospital, University of Madison Wisconsin with the help of Dr. Ewanowski, the first was for measuring the displacement of the front part of the tongue during the production of emphatic and non-emphatic-emphatic counterparts. The second was for reporting on the inward movement of the lateral walls of the pharynx during the production of emphatic sounds. . These experiments were conducted by means of an ADR Real-Time ultrasonic scanner, model 2130 used in imaging the configuration of the front part of the tongue in one session and the motion of the lateral walls of the pharynx in another session during the production of emphatic and non-emphatic utterances in Arabic. The images of the tongue configuration are displayed on the TV monitor screen in the sagittal plane showing the surface and internal structures of the tongue. The motion of the lateral walls of the pharynx is imaged by using a time motion method of display where a line on the screen represents a moving surface and tracing its motion; a downward displacement of the line on the screen represents an inward movement of the lateral walls of the pharynx. It was only possible to run one subject, the author, for the two experiments. The whole processes were videotaped and later on the relevant images with measurements shown on them were transferred to

photographic film. 18 words from Jordanian Arabic were selected containing 16 geminate consonants and one vowel for the tongue experiment:

Non-emphatic	Emphatic
/s/ 74 /ħassaba/ "he expected"	/s̲/ 70 /ħassaba/ "got measles"
/X/ 81 /naXXala/ "he sieved"	/X̲/ 74 /maXXata/ "he cleared nose
/ʕ/ 74 /naʕʕama/ "he ground"	/ʕ̲/ 72 /maʕʕata/ "he pulled hair"
/ħ/ 77/kaħħala/	/ħ̲/ 79 /kaħħata/ "he scratched"
/i:/ 85 /si:b/ "leave!"	/i:̲/ 81 /si:b/ "touch"
/d/ 80 /ħaddada/ "he planned"	/d̲/ 76 /ħaddara/ "he prepared"
/b/ 70 /ħabbaba/ "he made likable"	/b̲/ 60 /Xabbara/ "he informed"
/m/ 85 /ʔamma/ "he guided"	/m̲/ 56 /ʔamma/ "mother"
/k/ 84 /ħakkama/ "he authorized"	/k̲/ 81 /ħakkara/ "he fenced"

The transducer was placed manually under the chin of the subject, after it had been oriented precisely to capture the clearest image of the tongue configuration. Measurements were used by means of a digitizer. Two cursers were used, one with a fixed position on a horizontal line representing the place of the transducer and the second in play, being moved to the highest point of the tongue. The digitizer then calculated the vertical distance between the two cursors in mms and this was logged at the base of the image. The above table shows the vertical distance in mms between the surface of the tongue and the fixed point on the transducer during the production of the 18 sounds. It also shows the depression of the front part of the tongue during the production of the emphatic and non-emphatic counterparts. The highest point on the surface of the tongue during rest position was 74 mm. The table shows that apart from the case of /ħ/ there is a depression of the upper surface of the tongue during the production of the emphatic sounds as compared with their non-emphatic counterparts.

The lateral wall experiment was used to investigate the extent of the motion of the lateral wall of the pharynx. The ultrasonic transducer was placed below the angle of the mandible of the subject on the side of the wall of the neck. The scanning head was oriented until a large echo was located at the lateral wall of the pharynx. The subject then was asked to produce emphatic words and non-emphatic counterparts as well as some sounds in isolation. The motion of the left lateral wall of the pharynx appeared on the monitoring screen as a moving surface which was depressed during the production of emphatic items. This depression represents an inward movement of the left lateral wall of the pharynx during the production of emphatic sounds. The images were frozen and changed into photographic film. The material used was:

Non-emphatic	**Emphatic**
/ta:b/ "he turned from sin"	/t̲a:b/ "he recovered"
/sa:b/ "he left"	/s̲a:b/ "he touched"
/faðð/ "brilliant"	/f̲aðð/ "harsh"
/walla/ "he left"	/w̲alla/ "I swear"
/ħ/	/ħ̲/
/s/	/s̲/

The digitizer in the ultrasonic unit was used for measuring the left wall movement during the production of /s/ and /s̲/. The vertical distance from a fixed point on the transducer and the surface of lateral wall of the pharynx was (39 mm) for /s̲/ and (33 mm) for /s/ a difference of (6 mm). At the rest state, the distance was (35 mms). For the rest items no measurements were attempted, but the images show clearly that the lateral wall of the larynx is displayed during the production of the emphatic items compared to its non-emphatic counterparts.

5. THE FIBEROPTIC EXPERIMENTS

Use was made of two experiments to study the function of the larynx, the velum, the back part of the tongue and epiglottis during the production of all Arabic sounds. The author was the only single subject due to the availability of the technique . The first experiment was conducted at the Phonetics Laboratory of the Linguistics Department of UCLA with the help of Prof. Peter Ladefoged. A fiber bundle with an external diameter of 5mm was inserted into the pharyngeal cavity through the left nostril and positioned in the oropharynx above the epiglottis just below the velum and above the surface of the tongue. The subject produced all the Arabic sounds including the pharyngeals in words and in isolation, three times, each with a sentence frame. The images were recorded with sound on color video-tape. The second experiment was conducted at the Haskins Labs, New- Haven, U.S.A. with the help of Dr. Tom Boar . Two bundles were inserted one through the left and the other through the right nostril. The left one was positioned deeper in the pharynx than the right one and it was possible to view clearly the vocal cords, the arryeppiglottic folds, the upper edge of the epiglottis and in certain cases the root of the tongue. The right one was positioned above the surface of the tongue and it was possible to observe the movement of the back of the tongue, the upper edge of the epiglottis, the arryeppiglottic folds and the vocal cords. But the vibration of the vocal cords was observed clearly only through the left one. The two bundles gave two separate images. The images were recorded by means of a 16mm Cine Camera with a rate of 50 frames per second. A synchronizing pulse timing was placed simultaneously on the film and the audio signal. The subject read a list of meaningful minimal or semi-minimal word pairs of emphatic and non-emphatic items three times in a random way – the images were copied with the speech sounds each image represents. Observing the mobile images shows the retraction and lowering of the epiglottis for the pharyngeal sounds /ħ̲/ and /ʕ/ against the back wall of the pharynx in the laryngopharyngeal area and simultaneously a constriction taking place in the laryngeal vestibule, hence a kind of glottalization takes place. The arytenoids move upwards adding to the constriction. The narrowing was found to be maximum where the pharyngeal is geminate or at the beginning or end in the utterance. The retraction of the tongue looks folding up. The constriction between the epiglottis and the back wall of the pharynx was found to be narrower during /ħ̲/ than /ʕ/. Esling (1999:349) identified voiceless pharyngeal / ħ̲ / by aryepiglottic fold constriction and medial aperture and the voiced pharyngeal /ʕ/ by aryepglottic constriction and covered glottis. Trilling can

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occur laterally along the aryepiglottic folds in either voiced or voiceless or voiced approximant mode. During the production of /ħ/ the epiglottis moves backwards and forwards as if it were vibrating. This vibration-like movement is responsible at the acoustic level for the formant like structure which can be seen in the spectrograms; where there is no such vibration, no formant-like structure for the /ħ/ sound. The glottis was open during /ħ/ but the vocal cords were vibrating during /ʕ/.

The pharyngeals can be emphatic and non-emphatic; for the emphatic items F2 is lower and F1 is higher. The means of the means of the F1, F2 and F3 values of the sounds /ʕ/(702, 1427, 2315) and /ʕ̲/(750, 1163, 2243) as produced by four native speakers of Jordanian Arabic in the words /ʕa:ri/ "naked" and /ʕ̲a:ri / "my shame".

The images for the emphatic sounds show that the glottis is slightly smaller for the emphatic than the non-emphatic counterparts. For voiceless plosive this difference is much greater and this is reflected in the differences in values of the VOTs in milliseconds as follows; ti =35, t̲i=16, ki=52, k̲i=45, qi= 16. This is reflected in the difference between the size of the images for these sounds. For the emphatic /t̲/ and /q̲/ the size of the glottis on the pictures is much smaller than those of the corresponding /t/ and /k/.

5. DISCUSSION

The major articulatory mechanisms involved in the production of the emphatic sounds are:

1- The back of the tongue and the attached upper edge of the epiglottis are retracted towards the back wall of the pharynx and in most cases they are lowered. This results in a narrowing along the pharyngeal cavity, the maximum of which is at the level of the 3rd and 2nd cervical vertebrae.

2- The oral cavity is widened by lowering the palatine dorsum of the tongue due to the lowering and retraction of the back of the tongue and lowering of the mandible. This oral mechanism causes the raising of F1 and lowering of F2.

3- The soft palate is stretched down and the tip of the uvula is more curved forward than in the non-emphatic sounds. As the tip of the uvula points forward it approaches the dorsum of the tongue. The amount of lowering of the soft palate often seems greater than the amount of lowering of the dorsum of the tongue. This displacement of the velum and the uvula results in a narrowing in the velo-glossal cavity.

4- The mandible is lowered and retracted.

5- The lips are slightly rounded and protruded.

6- I agree with Esling (1996, 1999) for considering the aryepiglottalic sphincter mechanism as the primary point for constriction of the pharyngeal consonants. A Jordanian cancer patient whose epiglottis was removed produced the pharyngeal sounds normally. The narrowing for these sounds takes place in the laryngopharyngeal cavity; for emphatic sounds it takes place along the whole pharyngeal cavity. The pharyngeal consonants function as non-emphatic or emphatic according to the contest. The larynx is raised during the production of pharyngeal consonants, but for the emphatic sounds is raised for some and lowered for others, Loren Trigo (1991). The retraction of the root of tongue towards the back wall of the pharynx and lowering the paletine dorsum of the tongue during the production of emphatic and pharyngeal sounds have been reported by almost all physiological studies on emphasis and pharyngeals eg. Al-Ghazali, S., 1977;

5. CONCLUSION

This study shows that the feature emphasis in Arabic involves a narrowing along the whole length of the pharyngeal cavity with a maximum at the level of the 2nd and 3rd cervical vertebrae, a narrowing at the glosso-velar cavity and opening in the oral cavity and that these displacements have been measured. It confirms the general findings of previous writers, but goes further by giving quantitative statements. Another new finding is that the raising or depressing of the larynx is not directly related to emphasis as it is depressed for some sounds and raised for others; but it is always raised for pharyngeal consonants. The present work agrees with some scholars that the primary mechanism for producing pharyngeal consonants is related to constrictions taking place in the larynx.

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