An Acoustic Phonetic Analysis Of Fortis- Lenis Consonants In English And Arabic
تحليل صوتي فيزيائي نلأصواث الصامتة الشديدة والرخوة في اللغتين الانكليزية والعربية
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This work is a trial to investigate the nature of fortis and lenis consonants in English and Arabic and to what extent does such a dichotomy varies in these two languages.

Key words: Fortis, Lenis

1- Introduction:
In English, sounds are classified according to three main parameters: place of articulation, manner of articulation and energy of articulation, i.e. whether a given sound is fortis or lenis, depending on the muscular effort spent and the breath force used.

Fischer-Jørgensen (1975:160) describes fortis sounds in two scenarios: scenario one is acoustically- oriented in that fortis sounds have longer duration of the ready state portion of the sound with a sharper defined resonance region in the spectrum and time. Scenario two is genetically – oriented with a deliberate execution of the required gesture resulting in a lastingly stationary articulation; greater deformation of the buccal tract from its neutral, central position and heightened air pressure. Fortis consonants in this case are defined as those sounds articulated with a relatively strong degree of muscular effort and breath force as compared with other lenis consonants.

Most languages have a contrast of a kind similar to the fortis- lenis contrast found in English. But the exact form varies from one language to another. The present research tries to investigate the fortis-lenis
dichotomy in English and Arabic, and to what extent does such a dichotomy vary in these two languages.

2-The characteristics of English Fortis –Lenis consonants:-

Fortis consonants are defined as sounds made with a relatively strong degree of muscular tension and breath force (Fischer-Jørgensen, 1975:160; Hawkins, 1984:99; Laver 1994:343, Crystal, 2003:187 and Collins and Mees, 2008:50). The English consonants /p/ and /b/ are both bilabials (place of articulation) and plosives (manner of articulation), yet they are not identical. The same goes for /ø/ and /ð/, which are both dentals and fricatives, but are clearly very different.

Laver (1994:343) expounds that there are various phonetic features having different values depending on the given segment whether it is fully voiced or voiceless. These factors are: 1) potentiality and 2) the degree of the muscular effort being exerted throughout the vocal system, mainly the muscle system of the supralaryngeal vocal tract. Fischer-Jørgensen (1975:160) adds that fortis sounds are acoustically longer in duration and time than their lenis counterparts and genetically, there is a deliberate execution of a given gesture resulting in: 1) a lastingly stationary articulation, 2) greater deformation of the buccal tract from its neutral position and, 3) a heightened pressure.

The argument would then run on to say that the change from a fortis voiceless segment to a lenis voiced one is not a change of the phonatory state from vibrating vocal folds to an open glottis; since factors like the overall muscular tension, potentiality, and the breath force used must all be taken into consideration.

2-1 The Articulatory characteristics of English Fortis Consonants:

Place of articulation as a main parameter in the production of speech sounds refers particularly to the point in the vocal tract at which the main closure is made; whether at the lips, the teeth, the soft or the hard palate. Taking into consideration that the fortis- lenis dichotomy applies to the obstruents, i.e. stops and fricatives and to the affricates, then these sounds
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are made by closing or narrowing the vocal tract at various places respectively (Ladefoged and Maddisson, 1996:9 and Ladefoged, 2001:99).

Plosives include three groups of sounds: 1) the bilabials /p,b/ in which both lips are involved, 2) the alveolars /t,d/ in which the blade of the tongue touches the alveolar ridge and 3) the velars /k,g/ in which the back of the tongue articulates with the soft palate (Roca and Johnson, 1999:3-25; Davenport and Hannahs, 2005:8-18; Ladefoged, 2006:56-66; Collins and Mees, 2008:79-96).

Fricative sounds, on the other hand, include the following: 1) the labiodentals /f,v/ made by the lower lip touching the upper teeth, 2) the dentals /θ,ð/ made by the tongue-tip touching the inside of the upper teeth, 3) the alveolars /s,z/ in which the blade touches the alveolar ridge, 4) the palato-alveolars /ʃ,ʒ/ in which the blade articulates with the alveolar ridge with a simultaneous raising of the front of the tongue towards the hard palate and 5) the glottal /h/ made by the vocal folds coming together to cause a closure or a friction.

2-2 The Manner of Articulation:

This parameter refers to the type of constriction or movement that happens at any place of articulation such as the marked degree of narrowing, or a closure with a slow release. It refers to the configuration adopted by the speech organs in articulating a sound, and treats differences in the activity of the vocal organs (Langacker, 1972: 260; Wardhaugh, 1977:37-38, Todd, 1987:15 and Carr, 1993:1). Three types of manner of articulation will be focused on here, namely plosives, fricatives and affricates.

The articulation of plosive sounds (also known as stops) requires a complete closure at some point in the vocal tract; thereby blocking the airstream completely and momentarily, preventing the escape of air from the mouth (Hill, 1958:58; Catford, 1968:322, and Crystal, 2003:357). Since the mouth is blocked, there is a pressure built up behind the point of articulation as the air tries to continue flowing. This is followed by a brief period of a complete silence, then, the air is released with a short explosive noise, known as "plosion".

Laver (1994:133-34) assumes that there are three phases of plosive sounds: 1) the "onset phase" also known as the "closing phase" as there is an articulatory transition towards "complete closure", 2) the "medial
phase" also known as the "closed phase" since it lasts from the moment
the closure ends, and 3) the "offset phase" which is referred to as the
"release phase" as it begins at the moment that the complete closure
ends.

Roach(2001:44) adds that the third phase is usually followed by
aspiration which usually takes place when there is a "voiceless" interval
consisting of a strongly expelled breath between the release of the plosive
and the onset of the following vowel. Aspiration, as a feature,distinguishes the voiceless plosives from their voiced counterparts.
Some phoneticians ( O'Connor,1967:39-41; Hudson,1984:39 and
Crystal,2003:33) aver that voiceless plosives are aspirated when they
occur in initial and final positions of words as in pen /pʰ en/ and reap
/ri:p/. Also, when /p,t,k/ are followed by /l,r,w,j/ as in : play /pleɪ/, train
/treɪn/, and twin /twɪn/, etc. Furthermore, /p,t,k/ may have weak or no
aspiration if they precede a vowel in an unaccented syllable, as in
polite/ˈpəlaɪt/, or if they occur in final position as in lip /lɪp/. Moreover, /p,t,k/ lose their aspiration when they are preceded by /s/ in
initial position, as in star /stɑː/. Consequently, /p,t,k/ become unaspirated
similar to their voiced counterparts /b,d,g/.

Fricative sounds are produced when two articulators are brought very
close together leaving only a very narrow channel through which the air
sequeezes on its way out producing turbulence in the process, and so there is a hissing noise associated by them (Ladefoged,1972:9;
Shane,1973:18; Maddieson,1984:45; Todd,1987:16 and Roca and

Fricatives may be voiced or voiceless. Maddieson (1984:45) assumes
that voiceless fricatives "seem to be more numerous in the consonant
systems of the languages of the world than voiced fricatives". Fricatives
are voiced in medial and final positions as in although /əlðəʊ u/ and leave
/liːv/.

In producing affricate sounds, a stricture of a complete closure happens
followed by a "release phase" in which there is a close approximation
between the articulators and an audible friction is produced
is raised wth a total blockage of the air, with a gradual audible friction.
Affricate sounds are complex as they share properties with both plosives and fricatives, the first element of the affricate sound has a sharp plosive characteristic followed by a second element with an audible friction as Gimson (1980:171) puts it "any plosive, whose release stage is performed in such a way that a considerable friction occurs approximately at the point where the plosive stop is made, may be called affricative".

2-3 Voicing:
One of the primary features that differentiate the consonants of a language is voicing which depends on the functioning of the vocal folds- vibrating vs. non-vibrating – contributes significantly in classifying speech sounds into voiced and voiceless consonants respectively (Ladefoged, 1971:11; Laver, 1994:192 and Clark and Yallop, 1995:11).

Laver (1994:192) adds that during the vibration of the vocal folds, significantly known as "phonation", the vocal folds are adducted, blocking the airflow from the lungs and as a result, there will be a "respiratory pressure" from the pulmonic egressive air-stream mechanism builds up; and a subglottal pressure, then, becomes sufficiently high that it momentarily forces the folds apart, and the compressed air below the glottis bursts in short puffs through a narrow gap into the pharynx.

Laver (ibid:95-99) presents a model of vocal fold vibration known as the "Aerodynamic-Myoeelastic Model of Phonation", maintaining that the aerodynamic component refers to the relationship between the air-pressure and air-flow factors as the process of phonation is the use of the laryngeal system to generate an audible source of acoustic energy which can then be modified by the rest of the vocal apparatus. The myoeelastic component, on the other hand, concerns the contribution of mechanical factors in the muscles that position the vocal folds and their associated cartilages.

Sommerstein (1977:105) and Pennington (1996:247:9) assume that during the production of most voiceless speech sounds, the glottis is open and the vocal folds are abducted, so that the air passes freely between them, i.e. there is no vocal folds vibration.

The sounds under investigation: plosives, fricatives and affricates can take on one of these two voicing values; either voiced or voiceless. However, some of these voiced consonants like /b, d, g/ may be produced with full voice than elsewhere when they occur between voiced
consonants or vowels as in library/laɪbrɪ/ , or they may be partially voiced in initial positions as in bank/bæŋk/ or devoiced in final positions as in rub/raʊb/.

2-4 The Acoustic Characteristics of English Fortis Consonants:
Ladefoged(1993:199;2001:48) and Roach(2001:43) observe that plosives occur in various acoustic forms, depending on their articulatory characteristics, in that the articulation of each of them requires a momentarily complete blockage of the vocal tract at some point, so that the air cannot escape. For instance, /p/ and /b/ are formed when the lips are firmly closed, as in pie /paɪ/ and buy /baɪ/; /t/ and /d/ when the tip of the tongue blocks the vocal tract by forming a closure just behind the upper front teeth, i.e., against the alveolar ridge, as in two /tuː/ and do /duː/; and /k/ and /g/ when the back of the tongue is raised to make a closure against the roof of the mouth, as in coal /kɔːl/ and goal /ɡɔːl/.

Each of these consonants then forms a quickly changing sound and that the resonances of the vocal tract, i.e., the "formants" are produced while the plosive closure is being formed or is opening. That is, when the shape of the vocal tract is changing, the formant frequencies are moving.

Ladefoged(1993:199;2001:49-51) and Roach(2001:43) describe the movements of the formants as the distinguishing characteristics of the plosive consonants. Firstly, the movement of the first formant simply marks them as having a stop closure and its frequency increases when the plosive consonants are at the beginning of the syllable, and falls when they are at the end. Secondly, the movements of the second and third formants distinguish these sounds from one another. For instance, the sound is bilabial /p,b/ if a word or syllable starts with both the second and third formants increasing in frequency, the sound is alveolar /t,d/ if the third formant falls and the second formant has only a small movement, and the sound is velar /k,g/ if the second and third formants are closer together just after the stop has been formed, then the back of the tongue has contacted the roof of the mouth. However, at the ends of words like: lamp /læmp/, knob /knɒb/, what /wɒt/, understand /əndəstɜːnd/, book /bʊk/ and dog /dɒg/, the articulation of the plosives /p,t,k,b,d,g/ affects the movements of the above mentioned three formants in reverse ways.
An important acoustic characteristic of /p,t,k/ is that when these plosives occur initially, each of them is released with a burst of noise or small explosion. These voiceless plosives are known as aspirated stops. However, when they occur in final positions, the bursts of noise are often not produced; but are more commonly heard when the next word begins with a vowel. Instead of the silence one finds in voiced plosives, one can hear the vibration of the vocal folds coming from the larynx when producing the voiced plosives /b,d,g/. This action of the vocal folds has a definite pitch and overtones corresponding to a particular vocal tract shape.

Voicing is one of the main differences between the fortis voiceless plosives and their voiced lenis counterparts. Roach (2001:44) states that the first important component of the voiceless plosive is silence (represented by a gap in spectograms), which normally results in when the words begin with a momentarily complete closure of the vocal tract. Roger (2000:160) mentions that these sounds are distinguished by the effect they have on their neighbouring sounds. He introduces the sequences /pɜ, tɜ, kɜ/ for illustration, stating that in moving from the /p/ to /ɜ/, the mouth changes shape in a particular fashion; whereas the mouth changes its shape in different fashions from /t/ to /ɜ/.

Roger (2000:162) and Roach (2001:43) clarify that fricatives are generated by a turbulent airflow through various channels. Both voiced fricatives and their voiceless counterparts are similar in their characteristics in that they are produced with friction, i.e., the resistance to the air as it rushes through a narrow gap. Yet, there are three differences between voiced and their voiceless fricatives: 1) the first difference is due to the action of the vocal folds, i.e., voiced fricatives are produced with vocal folds vibrations which causes resonances in the cavities behind the narrowing; whereas voiceless fricatives are produced when the vocal folds are held apart so that they don't vibrate, 2) there is an acoustic difference between voiced and voiceless fricatives. The latter sounds comprise a periodic sound wave, i.e., a type of sound wave which doesn't have a regularly repeating pattern of vibration, and a hissing noise combined with the vibration of the vocal folds, which is periodic, i.e., a pattern of vibration which repeats itself at regular intervals, and 3) although voiced and voiceless fricatives are usually easy to distinguish from other sounds
In spectograms by their random noise pattern, they are not easy to distinguish from one another.

Roger (2000:162) states that sometimes /f, v, φ, ð/ are so weak that they barely show up at all in spectograms; whereas /s, z, Ъ, ʒ/ usually appear with energy in higher frequencies ranging between 4000-8000 Hz with /s, z/ and 2000-6000 Hz with /Ъ, ʒ/.

Roach (1993:73; 2001:45) describes English affricates as complex sounds as the acoustic characteristics of both the voiceless affricate /Ъ/ and the voiced /ъ/ are appropriate to plosives and fricatives. This goes on to mean that the initial portion of the voiceless affricate /Ъ/ is a plosive accompanied by a silence, and the released stage is a fricative sound which is a periodic. The initial portion of the affricate /ъ/, on the other hand, is accompanied by vocal folds vibration which is periodic, and the released stage is a fricative sound, which is a mixture of periodic and a periodic sounds.

3- The Characteristics of Arabic Fortis-Lenis Consonants:

Classic Arab phoneticians agree that fortis consonants are those sounds that are produced when the flow of air out of the mouth is blocked; whereas modern Arab phoneticians use either the terms used by classic phoneticians or those used by western phoneticians like Vendyres, De Saussure and Jan Kantiano. This goes on to say that fortis consonants refer to one of the features that characterizes the sounds along with voicing.

Bisher (2000:245) and Omar (2000:322) classify fortis consonants according to the type of constriction that happens at the vocal folds; whereas Al Bakoosh (1987:4) and Al-Hamad (2002:102) classify them according to the degrees of opening at the vocal tract, i.e., fortis consonants are produced when the vocal folds are completely closed as a result of the strength of the diaphragm.

In Arabic, sounds are either fortis /З, Ɂ, q, t, tъ, d, dъ, b, ɣ/ or lenis /h, ɣ, x, Ъ, s, ʃ, z, Ɂ, φ, ф/ or affricates /ъ, ʒ/. The remaining sounds like /r, m, n, w, y/ are classified as intermediate, i.e., neither fortis nor lenis.
3-1 **The Articulatory Characteristics of Arabic Fortis-Lenis Consonants:**

Place of articulation is a main parameter in describing consonants. It refers to the exact point in the vocal tract at which the main closure is made as mentioned earlier (see section 2-1). Taking into consideration that the fortis-lenis dichotomy applies to the stops and fricatives which are made by closing or narrowing the vocal tract at various places (Ayub, 1963:198; Al-Nuaimi, 1980:315; Al-Atyaa, 1983:45 and Al-Timimi, 2013:57).

Stops in Arabic include: 1) the bilabial /b/ produced by the upper and lower lips touching each other firmly, 2) the dentals /t, ʈ, d, ɖ/ made by the tip of the tongue touching the teeth, 3) the palatal /ʒ/ made between the mid of the tongue and the hard palate, 4) the velar /k/ made by the rear point of the tongue, 5) the uvular /q/ produced by the very end point of the back of the tongue, and 6) the glottal /Ɂ/ where the two vocal folds are firmly closed that no air can be pushed out through (Al-Ani, 1970:30; Omar, 2000:141; Bilqasim, 2005:284 and Al-Madani, 2012:25-6).

Fricative sounds in Arabic include: 1) the labio-dental /f/ articulated by the lower lip touching the inner part of the upper teeth, 2) the interdentals /φ, δ, ð/ made by the edge of the tongue touching the inner part of the teeth, 3) the dentals /s, ś, ʒ/ made by the tip of the tongue touching the teeth, 4) the palatal /ʃ/ made at the point between the tongue and the hard palate, 5) the velar /x/ articulated with the back part of the soft palate, 6) the uvular /γ/ made at the very back point of the soft palate, and 7) the glottals /h, ɦ/ where the vocal tract is narrowed and the vocal folds stop vibrating.

3-2 **The Manner of Articulation:**

This parameter refers to the type of constriction such as the marked degree of narrowing or closure with slow release (see section 2-2). Bisher (2000:245) and Omar (2000:322) classify sounds according to the type of the constriction that happens at some point in the vocal tract in three ways: 1) narrowing the vocal tract, 2) closing the vocal tract then there is a sudden release, and 3) closing the vocal tract then narrowing it; whereas Al-Bakoosh (1987:40) and Al-Hamad (2002:110) classify them according to the degrees of opening at the vocal tract, for instance, fortis consonants are produced when the vocal tract is completely closed as a
result of the strength of the diaphragm; whereas lenis consonants require a relative degree of opening.

The articulation of plosives requires a complete closure at some point in the vocal tract followed by a sudden opening causing a kind of plosion. They are also known as "stops" as the air is completely blocked. To articulate a plosive sound, then, two conditions must be met: first, to block the air coming out of the lungs completely at some point in the vocal tract so that the air is pressured behind, and second: to allow the pressured air to be out as two organs of speech be apart suddenly, causing thereby a plosion (Al-Hamad, 2002:102, Al-Madani, 2012:26, and Al-Timimi, 2013:57).

Omar (2000:117) assumes that the plosion that accompanies plosive sounds may be either explosive if the plosion is external or implosive if the plosion is anterior. He also says that plosive sounds may be accompanied by a breath of air and that this process is known as "aspiration", and the sounds produced in this case are known as "aspirated plosives".

Bisher (2000:247-8) avers that there are five places where the constriction happens: 1) the two lips, 2) The front part of the gum when the edge of the tongue touches it, 3) the soft palate when the back part of the tongue touches it, 4) the back part of the tongue (including the uvula), and 5) the larynx. Arabic plosive sounds are /b, t, ʈ, d, d̪, ʒ, k, q, Ɂ/.

Fricative sounds, on the other hand, are formed by narrowing the flow of air coming out of the lungs at some point in the vocal tract and allowing only a relatively narrow output to let the air go out slowly; making thereby a kind of friction. Fricative sounds in Arabic are /f, φ, Ʌ, Ʌ, s, s̪, z, ʃ, x, h, h, γ/ (Ai-Nuaimi, 1980:315; Bisher, 2000:30 and Omar, 2000:322).

3.3 Voicing:

Voicing is an important feature that characterizes Arabic consonants. It depends on the vibration of the vocal folds- vibrating vs. non-vibrating- and this contributes significantly in classifying speech sounds into voiced and voiceless. So voiced consonants are those sounds produced within the vibration of the vocal folds; whereas voiceless consonants are produced when the vocal folds stop vibrating.

Al-Nuaimi (1980:313) avers that classic Arab phoneticians define voiced consonants as " sounds that depend on the exact point of articulation, and
blockage of the flow of air"; whereas voiceless consonants as "weakly produced sounds with an open flow of air". This means that classic phoneticians depend on the movement of the air from the lungs or its stoppage. In this case, voiced sounds require the flow of air; whereas voiceless sounds require blocking the air till the given sound is produced. Al-Atyaa (1983:45) adds that the dependence of classic phoneticians on the flow of air causes a kind of overlap between classifying sounds as voiced and voiceless, or fortis and lenis; a matter which makes the distinction between these two features difficult. The voiced consonants concerned in this study are: /t, ŋ, h, x, s, s, t, f, q, k/; whereas their voiceless counterparts are /b, d, ð, ð, z, x, ʒ, ɣ/. Modern Arab phoneticians assume that /Ɂ/ is neither voiced nor voiceless, because the glottis is completely closed, a matter which departs the vibration of the vocal folds; preventing thereby the air to flow to the mouth till the glottis is opened to produce the so-called /Ɂ/.

3-4 The Acoustic Characteristics of Arabic Fortis-Lenis Consonants:

Al-Ani (1975:30) and Omar (1997;410) assume that consonants, generally speaking, have less acoustic energy than vowels, and that the consonants vary individually, making it easier to deal with them in groups, e.g., nasals, stops, etc.

Stops are physiologically characterised by two features: 1) the formation of a closure by one or more articulators in the vocal cavity where the driving pressure is blocked and 2) by the sudden release of that pressure. The build up of the driving pressure appears on the spectrograms as a gap of voiceless stops, and the sudden release appears as a burst. Al-Ani (ibid: 30-60) assumes that the acoustic characteristics of plosive consonants appear as follows:

1- In final position /b/ is in free variation-voiced or voiceless, released or unreleased. Its voicing appear on the spectrograms along the baseline about 250 cps with a duration of from 60-110 msec.

2- /ʒ/ in final position is in free variation, either voiced or voiceless. The duration of /ʒ/ is from 120-180 msec.

3- The /k/ appears on the spectrograms as a burst-random noise duration of 60-80 msec which is followed by a spike then a frictional noise withburst which ranges from 2500-3000 cps.
4- The /g/ appears as a strong burst which is indicated by a vertical spike that starts weakly at the baseline and rises to 3000 cps followed by a silence gap with an average of 30-40 msec with no noise and this refers to the lack of aspiration.

5- /t/ which is in free variation in final position, either aspirated, released or unreleased-mostly released. It appears as a burst with a relative duration of 40-60 msec in the form of a vertical spike followed by a gap which has a weak noise. The relative duration of the gap before the release is from 150-160 msec in final position.

6- /l/ is mostly unreleased in final position and is in free-variation. It appears in the form of a vertical spike of 20-30 msec duration followed by a gap with no noticeable noise.

7- /d/ is in free-variation in final position and is mostly unreleased. It appears on the spectograms like the /t/ sound except for voicing which is indicated for /d/ by the rt5tvoice bar with the duration of 80-100 msec.

8- /ʃ/ this sound is unaspirated with the duration of 80-100 msec.

9- / R / initially, it appears as a burst followed by a silence gap with duration of 15-20 msec, or as a short onset glide initiating the vowel formants following it. In final position, it is in free-variation. When released, the release is indicated by a burst that appears as a vertical line which may or may not be followed by a weak noise. This burst is preceded by a silence gap of 180-200 msec.

Fricative sounds are produced by a narrow constriction in the vocal cavity that causes the airflow to be consistently turbulent. Al-Ani (1975:33-60) avers that voiceless fricatives usually possess weak resonance structures appearing as a shadow of weak formants with little noise intervening. The spectographs appear as follows:

1- /f/ it appears as a random noise-duration which varies from 40-180 msec with the noise starting from about 1600 cps and up.

2- /ø / it also appears as a random noise duration of 80-130 msec.

3- /z/ this sound seems to possess three formants- f₁, along the baseline with 250 cps, f₂ with 1600 cps, and f₃ with 2400 cps. In upper frequencies, the /z/ contains a random noise-ranges from 3000 cps up to the top of the spectrum with a relative duration of 100- to 160 msec.

4- /ʃ/ it appears as a random noise with a relative duration of 120-17-msec in the upper frequencies of the spectrum. The noise starts at about
2000 cps. The /ʃ/ possess a higher frequency random noise spectrum than most of the other fricatives.

5- /x/ appears as a random noise that is concentrated and lacking below 1500 cps. The relative duration of /x/ is from 100-160 msec.

6- /γ/ this sound appears on the spectograms as a shadow of formant resonances, near the baseline, that are a continuation of f₁, f₂ and f₃. Occasionally, it has a very weak noise above f₃. The duration is similar to that of /x/.

7- /s/ appears as a random noise with duration of 100-170 msec starting approximately at 3000 cps. There appear to be some resonances in the form of very weak formants approaching vowel formants along f₂ at 1600 cps and f₃ at 2400 cps.

8- /s/ it is the counterparts of /s/. It appears as a random noise with the duration of 100-170 msec starting at 2750 cps.

9- /ð/ has a relative duration of 100-160 msec that is easy to detect because it possesses resonances that appear as weak formants with f₁ 275 cps, f₂ around 1500 cps, and f₃ 2450 cps.

10- /ð/ it has the relative duration as /ð/. It seems to possess resonances that appear as weak formants; f₁ 257 cps, f₂ 900-1000 cps and f₃ 2350 cps.

11- /h/ it has a duration of 100-160 msec and it is voiced when occurs intervocally. It appears as a noise concentrated around 2000-27000 cps and up and disappearing entirely below 1400 cps.

12- /h/ like /h/, it is voiced intervocally with a constriction formed by the dorsum of the dorsum of the tongue against the posterior wall of the pharynx where the movements of the pharyngeal muscles play an important role of 100-150 msec.

4- Description Of The Experimental Approach Used In This Study:

4-1 Procedure And Materials:

In order to obtain a corpus for analysis, two lists were compiled. The first list contained 31 English words and the second list contained 42 Arabic words. The total inventory included 73 individual words.

The individual words were typed on alphabetized index cards and were assigned a code number. Then two lists were prepared. The first list contained underlined words. The second list was typed without any
indication as to which words were under study and it was presented to the informants. Computer program recordings of the text were made in the sound labrotary of the department of English- University of Diyala of the academic year 2012-2013.

4-2 Informants:
Three informants were selected from class four of of the academic year 2012-2013. Informants A and B were males and informant C was female. All the speakers recorded first the total set of 73 words. Then they were requested to read the list of words arranged in pairs each with its own tempo, stress and intonation patterns, and they were instructed to use a reasonably uniform tempo and pitch patterns.

The above-described corpus was recorded on compact discs in the department of English- University of Diyala. The recordings were then submitted to a detailed spectographic analysis using the praat sound program.

4-3 The Spectographic Analysis of The data:
The spectographic analysis of speech transforms the acoustic patterns of speech into visual form. This research paper uses the following four kinds of analyses:

4-3-1 The Broadband Analysis:
This type of analysis displays the formant structure of voiced sounds, the energy concentrations of voiceless sounds, and a time pattern of changes in the frequency dimension. It uses a bandwidth of 300 cps to scan the acoustic spectrum.

4-3-2 The Narrow-Band Analysis:
This analysis shows the pitch of the stream of speech using a bandwidth of 45 cps.

4-3-3 The Amplitude Analysis:
Depending on the overall rectified waveform, the amplitude variations from one vocal fold cycle to another can be observed, they will show the intensity of each harmonic. Here the duration of the segment is the reciprocal value of the filter bandwidth of 1160 seconds.
4-4 **The Listening Experiment:**

The listening experiment comprises two tests. The first test contained 31 items of English fortis and lenis consonants and the second test contained 42 items of Arabic fortis and lenis consonants. Both tests were prepared, uttered by each of the three informants and then copied; depending on the way of analysis using the segmentation procedures of Lehiste (1960:16) and Hoard (1966:97).

The tests were then given to 30 non-native speakers of English (whose native language is Arabic). All of them were fourth stage undergraduate students of the department of English- University of Diyala of the academic year 2012-2013.

To gain perfect administration, all the students experienced the two tests under identical conditions. Harris (1969:114) states that "a perfect administration would be one that allowed the testees to perform at their best under identical conditions". The first listening experiment contained the following pairs of English words:

Table -1-
Results Of The English Listening Experiment

<table>
<thead>
<tr>
<th>pair</th>
<th>Correct identification</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>A</td>
</tr>
<tr>
<td>1- pill - bill</td>
<td>30</td>
</tr>
<tr>
<td>2- rope – robe</td>
<td>30</td>
</tr>
<tr>
<td>3- tie – die</td>
<td>28</td>
</tr>
<tr>
<td>4- seat – seed</td>
<td>28</td>
</tr>
<tr>
<td>5- coat – goat</td>
<td>27</td>
</tr>
<tr>
<td>6- ruck – rug</td>
<td>27</td>
</tr>
<tr>
<td>7- fail – veil</td>
<td>29</td>
</tr>
<tr>
<td>8- life – live</td>
<td>29</td>
</tr>
<tr>
<td>9- thigh - thy</td>
<td>29</td>
</tr>
<tr>
<td>10- bath - bathe</td>
<td>29</td>
</tr>
<tr>
<td>11- zeal – seed</td>
<td>28</td>
</tr>
<tr>
<td>12- case – gaze</td>
<td>28</td>
</tr>
<tr>
<td>13- share -</td>
<td>30</td>
</tr>
<tr>
<td>14- fish - garage</td>
<td>28</td>
</tr>
<tr>
<td>15- chill – gill</td>
<td>25</td>
</tr>
<tr>
<td>16- beseech – besiege</td>
<td>22</td>
</tr>
</tbody>
</table>
4-5 The Listening Test:

This section will discuss the results of the listening test presented in table -1- in a more detailed way. All three speakers were recorded while pronouncing the words in the listening experiment.

Figure-1-a Broadband spectrograms and amplitude displays of pill

Figure-1-b Broadband Spectograms and amplitude displays of bill

Figure-2 a Broadband spectograms and amplitude of rope

Figure-2-b Broadband spectograms and amplitude of robe
Figure -1-a and b clearly show that the resonances of the vocal tract are in low range because the lips are closed. The three formants move rapidly from a low starting point to a higher frequency in the vowel; Whereas figure -2- a and b show that the movement of the formants are reversed as the first formant moves down as the final stop is formed and the second and third formants move down reversing thereby the movement at the beginning of the words pill and bill.

Figure-3-a Broadband spectogram and amplitude of tie

Figure-3-b Broadband spectogram and amplitude of die

Figure-4-a Broadband spectogram and amplitude of seat
Figure-4-b Broadband spectogram and amplitude of seed

Figure-3-a and b show that the closure formed by the articulation of /t/ and /d/ at the beginning of the words tie /taɪ/ and die /daɪ/ has a certain vocal tract shape but this shape changes when /t/ and /d/ are released. This explains why the first formant goes up, the second formant moves very little whereas the third formant moves slightly down. Figure-4-a and b reveals that there is a downward movement of the second formant and an upward movement of the third movement.

Figure-5-a Broadband spectogram and amplitude of coat

Figure-5-b Broadband spectogram and amplitude of goat
Figure 6-a Broadband spectogram and amplitude of ruck

Figure 6-b Broadband spectogram and amplitude of rug

Figure -5- a and b show that the second and third formants in the words coat /kɔut/ and goat /gəut/ have very similar frequencies; whereas this is reversed in figure -6- a and b when /k/ and /g/ come at the end of words as in ruck /rʌk/ and rug /rʌg/ respectively as the second and the third formants come together.

Ladefoged (1993:199; 2001:49-51) explains how the movements of the formants can be the distinguishing characteristics of the plosive consonants. Firstly, the movement of the first formant marks them as having a stop closure with the frequency of the first formant increases when it occurs at the beginning of the syllable and falls when it comes at the end. And secondly, the movements of the second and third formants distinguish these sounds from one another. As such, if the second and third formants increase in frequency, the sound is 'bilabial'; if the third formant falls and the second formant has only a small movement, then the sounds are "alveolars", and if the second and third formants are close together and the back of the tongue touches the roof of the mouth, then the produced sounds are "velars".

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The fricative sound /f/ at the beginning of the word fail /feɪl/ in figure -7-a has noise spread over a wide range of frequencies; whereas figure -7-b shows that in the spectogram of the sound /v/ at the beginning of the word...
veil /ˈveɪl/, there is only a little random energy in the higher frequencies. Figure 8-a and b clearly show a turbulent airflow through various channels, i.e., they are produced with friction.

Figure 9-a Broadband spectogram and amplitude of thigh

Figure 9-b Broadband spectogram and amplitude of thigh

Figure 10-a Broadband spectogram and amplitude of bath
Figure-10-b Broadband spectogram and amplitude of bathe

Figure-9-a shows that the sound /ø/ has energy centered in the higher frequency range above 5,000 Hz and that the second formant is fairly level, at around 2,000 Hz. The spectographic analysis of the word thy /ðaɪ/ however, shows that there is only a little random energy in the higher frequencies of the sound /ð/. Figure-10-a and b show that the sounds /ø/ and /ð/ are so weak at the end of words that they barely show up at all in spectograms.

Figure-11-a Broadband spectogram and amplitude of seal

Figure-11-b Broadband spectogram and amplitude of zeal
Figure 12-a Broadband spectogram and amplitude of case

Figure 12-b Broadband spectogram and amplitude of gaze

Figure 12-a shows the spectographic analysis of the sound /s/ at the beginning of the word seal /siːl/ which has a large amount of energy and intense extending over 5000 Hz; whereas the sound /z/ at the beginning of the word zeal /ziːl/ shows a random energy in the higher frequencies. In figure 12 a and b the effects of the turbulent air-stream are clearly visible.

Figure 13- Broadband spectogram and amplitude of share
Figure-14-a Broadband spectogram and amplitude of fish

Figure-14-b Broadband spectogram and amplitude of garage

Figure-13- shows that the sound /ʃ/ at the beginning of the word share /ʃər/ has more energy at a slightly lower frequency centered at a little above 2,500 Hz. And the frequency of /ʃ/ at the end of the word fish /fɪʃ/ has a little random energy. Figure -14-b shows the analysis of the sound /ʒ/ shows that this sound has more energy at a slightly lower frequency centered at a little above 2,500 Hz./

Figure-15-a Broadband spectogram and amplitude of chill
Figures 15a and b and 16 a and b show four spectograms illustrating the acoustic characteristics of the voiced and voiceless affricates /ʧ/ and /ʤ/ at the beginning of the words chill /ʧɪl/ and gill /ʤɪl/, and at the ends of the words beseech /bɪifference/ and besiege /bɪisɪʤ/ respectively. In studying these figures, one finds that in analyzing the voiceless affricate /ʧ/ and the voiced /ʤ/, there is little to see for the initial sounds /t/ and /d/ and that the vertical striations are only visible in /ʃ/ and /ʒ/.

Figure-15-b Broadband spectogram and amplitude of gill

Figure-16-a Broadband spectogram and amplitude of beseech

Figure-16-b Broadband spectogram and amplitude of besiege
Table -2-
Results of the Arabic listening experiment

* Arabic Key Sounds are given in appendix -2- of this research paper
* The meaning of the words used in this table are given in appendix -3- of this research paper

<table>
<thead>
<tr>
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<td>3- kasar</td>
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<tr>
<td>4- fark</td>
<td></td>
</tr>
<tr>
<td>5- qamar</td>
<td>29</td>
</tr>
<tr>
<td>6- saʔiq saʔ</td>
<td>26</td>
</tr>
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<td>7- a- tal</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>matt</td>
</tr>
<tr>
<td>b-dall da l1</td>
<td>26</td>
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<td>c-saar</td>
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<td>mass</td>
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<td>8- ða</td>
<td>27</td>
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<td>faʔ</td>
<td>29</td>
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<tr>
<td>9- a- ðarwa</td>
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<td>raðð</td>
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<td>b-ðil</td>
<td>25</td>
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<tr>
<td>10- fawz</td>
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</tr>
<tr>
<td>baqaa</td>
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</tr>
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<td></td>
<td>25</td>
</tr>
<tr>
<td></td>
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</tbody>
</table>
Figure 17-a Broadband spectogram and amplitude of ʒɑːʔ

Figure 17-b Broadband spectogram and amplitude of ʃɑːʔ

Figure 18-a Broadband spectogram and amplitude of farraʒ

Figure 18-b Broadband spectogram and amplitude of farraʃ

Figure 17-a shows that the sound /ʒ/ has three formants, the first one starts slightly down, the second moves upward, and the third comes down.
again; whereas the sound /ʃ/ in figure-17-b seems to have a random noise with a relative duration of 120-170 msec in the upper frequencies of the spectrum. Figure-18-a shows that at the end of words, the sound /ʒ/ is in free variation, either voiced or voiceless, and the sound /ʃ/ at the end of words show a higher frequency random noise spectrum than most of the other fricatives.

Figure-19-a Broadband spectogram and amplitude of kasar

Figure-19-b Broadband spectogram and amplitude of xasar

Figure-20-a Broadband spectogram and amplitude of fark
In figure-19-a the sound /k/ appears on the spectogram as a burst-random noise duration of 60-80 msec which is followed by a spike and then a frictional noise. The sound /x/ in figure-19-b appears also as a random noise with the relative duration of 100-160 msec and lacking below 1500 cps. Both /k/ and /x/ seem to be random at the end of words in figures 20 a and b respectively.

Figure-20-b Broadband spectogram and amplitude of farx

Figure-21-a Broadband spectogram and amplitude of qamar

Figure-21-b Broadband spectogram and amplitude of γamar
Figure 22-a Broadband spectogram and amplitude of saʔiq

Figure 22-b Broadband spectogram and amplitude of saʔiʔ

Figure 21-a shows that the sound /q/ lacks aspiration as it appears as a strong burst indicated by a vertical spike followed by a silence gap. The sound /γ/ appears on the spectogram as a shadow of formant resonances. At the end of words; however, the sound /q/ starts weakly at the baseline and rises to 300 cps and the sound /γ/ appears as a continuation of f₁, f₂ and f₃.

Figure 23-a Broadband spectogram and amplitude of tal
Figure-23-b Broadband spectogram and amplitude of tal

Figure-24-a Broadband spectogram and amplitude of matt

Figure-24-b Broadband spectogram and amplitude of mat

Figure-25-a Broadband spectogram and amplitude of dall
Figure-25-b Broadband spectogram and amplitude of dall

Figure-26-a Broadband spectogram and amplitude of radd

Figure-26-b Broadband spectogram and amplitude of rad

Figure-27-a Broadband and amplitude of saar
Figure-27-b Broadband spectogram and amplitude of ŋaarr

Figure-27-c Broadband spectogram and amplitude of zaar

Figure-28-a Broadband spectogram and amplitude of mas

Figure-28-b Broadband spectogram and amplitude of mas
The dentals /t, t/, d, d, s, s, z/ are shown in figures 26a,b, 27a,b and 28a,b respectively. Firstly, the sound /t/ appears as a burst with a relative duration of 40-60 msec which has weak noise and in final position, it appears in free variation, aspirated and mostly released. The sound /t/ appears in the form of a vertical spike followed by a gap of no noticeable noise and it is mostly unreleased in final position. The sound /d/ appears like /t/ in spectograms except for voicing, and it is also in free variation in final position. The spectogram of the sound /d/ shows that it is unaspirated with the duration of 80-100 msec. The sound /s/ appears as a random noise in the spectogram with the duration of 100-170 msec and the sound /s/ is the counterpart of /sl/ except in voicing. The spectogram of /z/ shows that this sound has three formants $f_1$ with 250 cps, $f_2$ with 1600 cps and $f_3$ with 2400 cps.
Figure-29-b Broadband spectogram and amplitude of haða

Figure-29-c Broadband spectogram and amplitude of haða

Figure-30-a Broadband spectogram and amplitude of faʔ

Figure-30-b Broadband spectogram and amplitude of fah

Figure-30-c Broadband spectogram and amplitude of fah
The glottal sounds /ʔ, Ɂ, ħ/ are shown in figures 29 a, b and c and 30 a,b and c. The sound /ʔ/ appears initially either as a burst followed by a silence gap or as a short onset glide initiating formants of the following vowel; whereas in final position, it is in free variation. The spectogram of the sound / h / shows that it is voiced when occurs intervocally that appears as a noise concentrated around 2000-27000 cps. Like /h/ the sound / ħ / is voiced when it occurs intervocally with a constriction formed by the dorsum of the tongue against the posterior wall of the pharynx.

Figure 31-a Broadband spectogram and amplitude of ɗarwa

Figure 31-b Broadband spectogram and amplitude of ņarwa
The interdental sounds /ð, ø, ð/ are shown in figures 31 a and b, 32 a and b and 33 a and b. The spectogram of the sound /ð/ appears as weak formants with \( f_1 \) 275 cps, \( f_2 \) around 1500 cps and \( f_3 \) 2350 cps and that is why it is easy to detect whether it occurs initially or finally. The sound /ø/ has the same relative duration as /ð/. The sound /ø/ appears as a random noise duration of 80-100 msec.

Figure-34-a Broadband spectogram and amplitude of fawz
Figures 34 a and b and 35 a and b show that the sound /f/ appears as a random noise duration which varies from 80-140 msec. The spectogram of the sound /b/ shows that it appears along the baseline at about 250 cps to reveal its voicing and in final position it is in free variation.
Conclusions:
- In English, the terms fortis and lenis are used to distinguish between the pairs of plosives, fricatives and affricates on the basis of energy of articulation.
- Fortis and lenis refer to sounds characterised by higher air-stream pressure and muscular tension in the organs initiating them.
- Fortis and lenis plosives, fricatives and affricates are classified in terms of their articulatory characteristics depending on three criteria: 1) place of articulation, and the contribution of articulators in producing them, 2) manner of articulation, how the sounds are produced in accordance to the degrees of constriction, and 3) voicing, depending on the vibration of the vocal folds.
- Fortis and lenis plosives, fricatives and affricates can also be classified in terms of their acoustic characteristics by the propagation of the sounds in terms of sound waves that move from the speaker's mouth to the listener's ears.
- The way speakers produce speech sounds influences how listeners perceive and recognize them due to speech production.
- English plosives can be discriminated by the feature of aspiration as it relates to voiceless plosives, so voiced plosives are not aspirated.
- English plosives occur in various acoustic forms depending on their articulatory characteristics, in that the articulation of each requires a momentarily blockage of the vocal tract at some point to prevent the escape of air.
- English fricatives relate to turbulent airflow through a narrow channel and so they display a great amount of energy in higher frequencies.
- The released stage of an English affricate is a mixture of periodic and a periodic sound.
- The researcher finds that only few of the 31 items of the English test were answered correctly by all the informants, viz. the initial fortis plosives /p/ and /t/.
- In Arabic, the term fortis is used to refer to one of the features that characterizes the consonant sounds along with voicing.
- In Arabic, fortis consonants are classified either to the type of the constriction that happens at the vocal folds or to the degrees of opening at the vocal tract.
- In Arabic, fortis consonants are produced when the vocal folds are completely closed as a result of the strength of the diaphragm.
- The plosion that accompanies Arabic plosive sounds may be either explosive if the plosion is external or implosive if the plosion is interior.
Arabic plosive sounds may be accompanied by a breath of air known as "Aspiration" and the produced sounds then are "aspirated plosives".

Arabic plosives appear on the spectograms as a gap of voiceless stops followed by a sudden release that appears as a burst.

Arabic fricative sounds are formed by narrowing the flow of air coming out of the lungs followed by a narrow output to make the air escapes causing thereby a kind of friction.

In the spectograms, Arabic fricative sounds appear as high random noises as the air is consistently turbulent.

Voiced Arabic fricatives usually possess weak resonance structures appearing as a shadow of weak formants with little noise intervening.

The distinction between voiced and voiceless sounds and fortis and lenis consonants is not clear cut in Arabic as classic phoneticians depended on the flow of air to determine both dichotomies.

**Bibliography:**

- Ladefoged, Peter (1972) "Phonological Features And Their Phonetic Correlates". In Journal of the International Association 2.
Appendix -1-
The phonemic transcription of the English words listed in table-1-

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<td>/taɪ/</td>
</tr>
<tr>
<td>seat</td>
<td>/siːd/</td>
</tr>
<tr>
<td>coat</td>
<td>/kɔut/</td>
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<td>/raŋk/</td>
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<td>thigh</td>
<td>/θaɪ/</td>
</tr>
<tr>
<td>bath</td>
<td>/bæð/</td>
</tr>
<tr>
<td>share</td>
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</tr>
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<tr>
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Appendix -2-
Arabic Key Sounds
Appendix -3-

The meaning of the Arabic words listed in table -2-

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<th>word</th>
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<td>to comfort</td>
<td>farraʃ</td>
<td>brushed</td>
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<td>kasar</td>
<td>broke</td>
<td>xasar</td>
<td>lost</td>
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<td>fark</td>
<td>to rub</td>
<td>farx</td>
<td>young bird</td>
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<td>qamar</td>
<td>moon</td>
<td>γamar</td>
<td>to immerse</td>
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<td>driver</td>
<td>saʔiγ</td>
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</tr>
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<td>hill</td>
<td>ʃal</td>
<td>drizzle</td>
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<td>belong to</td>
<td>matʔ</td>
<td>to stretch</td>
</tr>
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<td>dal</td>
<td>showed</td>
<td>dalʔ</td>
<td>get lost</td>
</tr>
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<td>radd</td>
<td>restored</td>
<td>raʃ</td>
<td>to bruise</td>
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<td>haʔa/ haʔa</td>
<td>imitated/hallucinated</td>
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<td>ʃarwa</td>
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<td>baqaa</td>
<td>remained</td>
<td>ʃab</td>
<td>to dissolve</td>
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تحليل صوتي فيزيائي للاصوات الصامتة الشديدة واللينة في اللغتين الإنكليزية والعربية

الملخص:
- تتسم الأصوات في اللغة الإنكليزية وفقًا لثلاثة معايير: مكان النطق و هيئة النطق و قوة النطق، أي فيما إذا كان الصوت شدودًا أو ليناً بالاعتماد على الطاقة العضلية المبذولة و قوة التنفس المستخدمة.
- تصف فيشر أورجنسن (1976: 161) الاصوات الشديدة في مشهدين: المشهد الأول ذو الاطار الفيزيائي بأن الأصوات الشديدة تتطلب امدا طويلا وترددا حادا في الحزمة والوقت، و المشهد الثاني ذو الاطار الجيني بأن الأصوات الشديدة تتطلب وقتا طويلا في نطقها وغلقا أو تضيقًا لمجرى النطق وضغطًا عاليًا في الهواء المحيوس و بهذا يمكن تعريف الأصوات الشديدة باءنها الأصوات التي تتطلب درجة قوية من الطاقة العضلية والتنفس بالمقارنة مع الأصوات اللينة.
- إن هذه المقارنة بين الأصوات الشديدة واللينة موجودة في معظم اللغات بما يتشابه مع اللغة الإنكليزية و تحت مسميات أخرى وصيغ مختلفة. ويُعده البحث الحالي لمحاولة لسر الغموض هذا الثنائي في قوة النطق في اللغتين العربية والإنكليزية ومدى تنوع هذا الثنائي من الأصوات الشديدة واللينة في هاتين اللغتين.

- الباحثة