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THE INFLUENCE OF FREQUENCY FILTERING ON THE PERCEPTION OF /ṣ/ IN ARABIC

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ملخص البحث:

من أهم ما يميز الأصوات المفخمة في اللغة العربية هو طريقة نطقها والتي يرجع فيها اللسان إلى الخلف قريبًا من الجدار الخلفي للفم. وتتمير الأصوات المفخمة أيضًا بقدرتها على التأثير في نطق الأصوات الساكنة والمتحركة المجاورة لها. تركز هذه الدراسة على نطق الأصوات المفخمة في اللغة العربية، خصوصًا صوت الصاد، وتهدف إلى تحديد ما إذا كان حذف بعض الترددات في صوت الصاد والأصوات المجاورة له سيؤثر على سماع الكلمة بشكل صحيح. تم تسجيل ستة أزواج من الكلمات التي تحتوي على السين والصاد، وتم تكرار هذه الكلمات ثلاث مرات. تم حذف الترددات الواقعة بين 1000 و 2000 هرتز. بعد ذلك، استمع ثمانية عشر متحدثًا باللغة العربية إلى التسجيلين، الأصلي والمعالج، وذلك لتحديد هوية هذه الكلمات.

أظهرت نتائج تحليل البيانات أن حذف الترددات خصوصًا من الصوائت المجاورة لصوت الصاد قد أثر سلبًا على تحديد هوية الكلمة بشكل صحيح. وقد لُوحظ أن هذا التأثير غالبًا ما يكون واضحًا في الكلمات التي لا تحتوي على أي أصوات تنطق في الجزء الخلفي من الفم. وقد لوحظ أيضًا بعض التأثير في كلمات مثل "قصر" لأنها تحتوي عي حرف القاف والذي ينطق في الجهة الخلفية من الفم. على الرغم من أن حذف هذه الترددات قد أثر سلبًا على تحديد

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الكلمة بشكل صحيح، من الواضح أنه عمل بشكل أكثر فعالية على الكلمات التي تحتوي على أصوات ساكنة أو متحركة منطوقة في الجزء الأمامي من الفم.

أخيرًا، وقبل تعميم هذه النتائج والتي أوضحت أن حذف بعض الترددات يؤثر سلبًا على تحديد الكلمة بشكل صحيح، يجب حذف ترددات أكبر، ويجب استخدام كلمات تحتوي على أصوات مفخمة أخرى للتحقق من مدى صحة النتائج ومن ثم تعميمها. سيساعد هذا في توضيح مدى تأثير حذف الترددات على وضوح الكلمات التي تحتوي على أصوات مفخمة، كما وسيحدد الترددات الأكثر أهمية لضمان وضوح الأصوات المفخمة.

The Influence of Frequency Filtering on the Perception of /ṣ/ in Arabic

Abstract:

This study aims to investigate the production and the acoustic correlates of /ṣ/ in Arabic. One of the main interesting facts about emphatic consonants is that their production can affect the production of the consonants and vowels in their vicinity. The aim of this study is to determine whether filtering the frequencies of the second formant of the vowels neighbouring /ṣ/ will affect the intelligibility of the word. Six minimal pairs with /ṣ/ and /s/ were recorded three times each. A band-stop filter was created and applied to the original recording to delete the frequencies between 1000 and 2000Hz. The original and the filtered recording were then played to eighteen native speakers of Arabic to determine the identity of these words.

Results from the analysis of the participants' responses showed some influence of filtering the second formant of the vowels on the perception of /ṣ/. This effect was mostly seen in words which did not

have any back consonants. Only some influence has been noticed in words like /qaṣr/, because the /q/ is a back consonant. Although the filter affected the perception and intelligibility, it is obvious that it worked more effectively on words containing front consonants and vowels.

Finally, in order to determine the influence filtering on intelligibility, it is very important to apply a different filter (to reject more frequencies) and to use more minimal pairs containing the rest of emphatic and plain consonants. This will help determine which frequencies are more vital in ensuring the intelligibility of emphatic sounds.

Introduction:

In the last few decades, there has been much research on the phenomenon of emphasis in Arabic. Emphatic sounds refer to a set of consonant sounds that are characterized by having a secondary articulation at the pharynx region. It is the retraction of the tongue and the narrowing of the pharynx passage that characterize the pronunciation of these sounds. The emphasis can travel from emphatic consonants to neighbouring consonants and vowels (Jongman et al. 2007: 914). Specifically, emphatic sounds cause the formants of /e/ vowel to go higher and others to drop, and affect perception, as a result. The issue of the perception of emphatic sounds and how filtering the

second formant of the vowel can affect intelligibility is investigated here. The aim of this paper is threefold. The first is to shed light on the mechanism involved in the production of emphatic sounds in Arabic, with a special attention to /s/ and /ṣ/. The second goal is to explore the acoustics of these sounds and the effect they have on vowel formants. Here, different studies are highlighted and summarized, so that the effect of these sounds is clear and understood. The major and last goal of this paper is dedicated to an experiment. In this experiment, recordings of six minimal pairs containing /s/ and /ṣ/ are filtered using a band-stop filter. This recording is then played to native Arabic-speaking listeners to identify the lexical items in both, the original and the filtered recording. The results of this paper should reveal whether or not rejecting certain formants from the vowels neighbouring the emphatic sounds will affect the perception of emphatic sounds, and hence determine their intelligibility.

The production of emphatic sounds:

In the production of /ṭ/, /ḍ/, /ṣ/ and /ẓ/ sounds in Arabic, the back of the tongue has a major role to play. In fact, the constriction caused by the retraction of the tongue is the source of emphasis. Centuries ago, Sibawayh (d. circa 796 A.D, cited in Bin-Muqbil, 2006:31) stated that in pronouncing emphatics, the tongue covers up all the area from their place of articulation to a part of the palate opposite to the tongue which is raised towards the palate. The constriction alone is not the only cause of emphasis. Laufer and Baer (1988, cited in Thomson, 2006:229) state that “In the production of emphasis, not only do the pharyngeal walls

constrict but the epiglottis tilts backwards and the tongue root is backed and lowered as well”

In order to understand the nature of the production of these sounds, some scholars compared them to their sibilants which have no emphatic value (they are called plain). Ibn Sina (translated by Semaan 1977: 41-42), for example, stated that the production of /ṣ/ is similar to that of /s/, except for that in /ṣ/ the passage of air requires a large surface of the tongue to be used. According to Ali and Daniloff (1972, cited in Kent and Read, 2002: 186) the posterior wall of the pharynx and the velum are not significantly involved in this articulatory difference. The only difference between emphatic and plain consonants lies in that the former has “an oropharyngeal constriction”. In addition, Ladefoged (2006: 166) states that the mechanism of producing emphatic sounds involves retracting the root of the tongue towards the rear wall of the pharynx. In this sense, Ladefoged (2006: 230) defines pharyngealization as “The superimposition of a narrowing of the pharynx”. Figure (1) shows the retraction of the tongue towards the pharynx region during the production of emphatic sounds, and how there is no retraction in the production of their place counterparts.

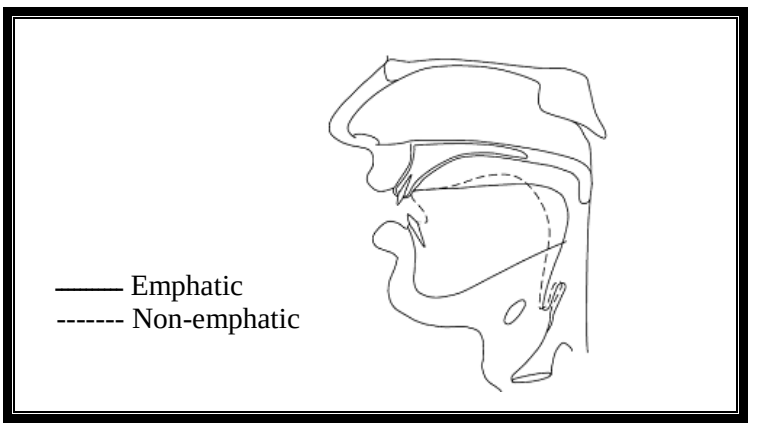

Fig (1) shows the retraction of the tongue towards the Pharynx. The picture is adopted from Bin Muqbil (2006: 32)

There are a number of well-known terms used in describing the process of emphasis in emphatic sounds. For example, Lehn (1963, cited in Bin-Muqbil, 2006) states that emphatics are called "pharyngeal zed, velarized, uvularized, retracted, strongly articulated, and heavy". The production of these sounds is problematic. This is the reason why there is no clear cut in describing them and this is why many linguists disagree on the nature of the their articulation. Pharyngeal sounds are similar to velarized sounds and, Arabic emphatic sounds are divided into these two categories (Catford, 2001; Ladefoged, 2006; Clark et al, 2007). Some of these sounds have other names in Arabic. 'Is¯am (1992: 214) states that /s/, /ṣ/, and /z/ are named 'Asalia' or epical sounds, because the epic of the tongue is the active articulator. Their places of articulation are very close as the /ṣ/ is pronounced at the back,

followed by the /s/ at the middle, and /z/ being the farthest front. In describing the mechanism of emphatic sounds' production, Ladefoged (1995: 169) argues that there are many gestures taking place at the same time and region.

Emphasis spreading:

Another interesting feature of "emphaticness" is that it spreads from a single segment to other segments preceding and following the emphatic sounds. In this respect, Michell defines emphasis as "A prosodic feature that extends beyond single consonant segments or even clusters to embrace one or more syllables and to include consonants and vowels that do not immediately abut on an unequivocally, so-called 'primary, emphatic consonants".

Mitchell (1993:111)

Thompson (2006:229) in addition, shows how sounds with primary or secondary pharyngeal constrictions affect sounds in the same vicinity by "pulling them lower and farther back in the mouth". It is worth mentioning that emphasis target consonants as well as vowels. For example, Norlin (1985, cited in Laver, 1994: 327) states that "pharyngealization often spread considerable back beyond the syllable-final segment, into the syllable-nuclear vocoid, distorting the onset to the vocoid". The direction of emphasis is another issue of investigation.

Emphasis spreads regressively and progressively. How far it can travel depends on the place of articulation of the consonants in the syllable or syllables. (Al-Nuzaili, 1993:33)

Acoustics of the emphatic sounds:

Emphatic sounds have a major influence on segments neighbouring them. Investigating the acoustics of the vowels in the vicinity of emphasis is unambiguous and can be traced. For example, the values of the first formant (F1) and the second formant (F2) of the vowels preceding and following emphatic sounds are affected. Ladefoged (1995: 167) points out that F1 and F2 come close together, and the value of F1 is around 1000Hz. Regarding the relation between emphatic-plain contrast and the change in vowel formants, Hassan (2005:127) states that F1 and F2 of the vowels preceding or following emphatic consonants tend to be closer than the ones surrounding non-emphatic consonants. Hassan (2005:127), in addition, argues that the acoustic analysis shows that the vowels in the vicinity of emphatic sounds tend to be longer than the ones in the vicinity of non-emphatic sounds. The nature of the vowel, in contrast, can be incongruously affected emphasis. For example, the lowering of F2 is different from vowel to vowel. While the vowel /æ/ will achieve the lowest F2, the values of F2 in the case of the vowels /i/ and /u/ are higher in comparison (Card 1983:85). The length of the vowel is another factor that determines emphasis. Norlin (1987:176) points out that the

differences of F2 in the vowels following emphatic and non-emphatic seem to be greater in the case of short vowels when both are measured at the midpoint of the vowel.

In conclusion, the aim of this introduction is to provide a clear picture for the mechanism involved in the production of Arabic emphatic sounds, and to look into emphasis spreading and the effect it has on the vowels preceding and following emphatic sounds. Emphatic sounds are characterized by having a secondary articulation at the pharynx. The constriction caused by the retraction of the tongue is the reason behind the emphasis. This emphasis can travel and influence segments in the neighbouring syllables. Emphasis targets the second formant of the vowel and decreases its value. Since emphasis is carried in other segments in the syllable(s), the question to be raised at this point is whether filtering this formant in the vowels preceding and following emphatic sounds will affect the perception of these emphatic consonants and intelligibility.

The experiment:

As stated earlier, an experiment was conducted to determine the role of F2 in carrying the emphasis of /ṣ/, and hence in determining the intelligibility of words with this emphatic consonant. The experiment was motivated by the fact that learners of Arabic look for cues in the

vowels neighbouring emphatic consonants to determine their identity (Hayes-Harb and Durham 2016). It's hoped that results from the identification task will answer whether or not filtering the vowel will influence the perception of the target words.

The material:

The material used in this study consists of six minimal pairs containing /ṣ/ and /s/. The list of these words and their translation and gloss is in table (1). The list was randomly repeated three times which gives a sum of thirty-six items to be evaluated by the listeners.

	Emphatics		Non-emphatics	
	Word	Gloss	Word	Gloss
1-	/ṣari:r/ صرير	(N) the sound of grinding teeth	/sar:r/سرير	(N) = bed
2-	/faṣi:la/ فصيلة	(N) in Army, Platoon	/fasi:la/فسيلة	(N) a young tree
3-	/qaṣr/ قصر	(N) a palace	/qasr/قسر	(N) = using force
4-	/ṣu:ra/ صورة	(N) A photo	/su:ra/ سورة	(N) = A chapter in the Holy Quran
5-	/waṣama/ وصم	(V, past) to disgrace	/wasama/وسم	(V, past) = to decorate with a medal
6-	/haraṣa/ حرص	(V, past) cared about sth	/harasa/ حرس	(V, past) = to guard

Table (1): The six minimal pairs of /ṣ/ and /s/ used in the experiment.

The participants:

Eighteen participants took part in this study. All of the participants were male native speakers of Arabic from Tripoli. The age range for those participants at the time of the experiment was 20-43. The average age for male participants was 36 years. All participants were informally interviewed to verify that they did not have a history of any speech or listening disorders. After the listeners were recruited, they were asked to read the information sheet of this research, which was provided in Arabic, and sign a consent form, which was also provided in Arabic (See Appendix 2 enclosed). All participants were offered compensation for their time.

Procedures

After saving the recording, a band-stop filter with a centre frequency of 1400Hz and a band-width of 1200Hz was created. The filter was applied to the recording of the thirty-six words. Figure (2) shows the spectrogram of the first word, /faṣi:la/, in the original and in the filtered recording.

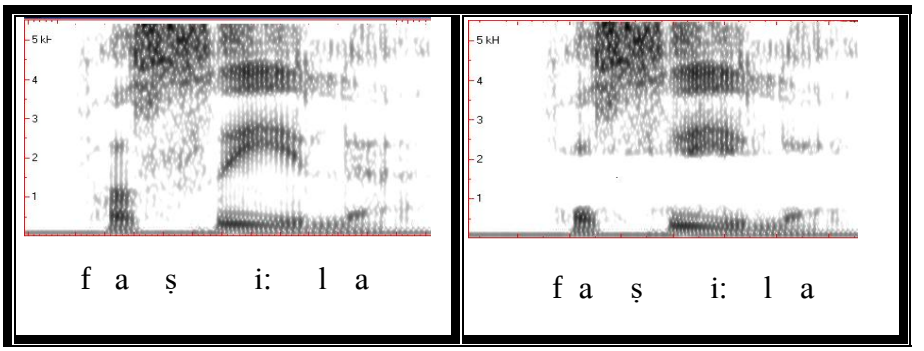

Fig (2) A spectrogram of the first word /faṣi:la/ in original recording (left) and in the filtered recording (right)

In a pilot study, 4 Arabic native-speaker listeners were asked to listen to the filtered recording and write down the words. There were three problems associated with this step. The first issue was that the participants were feeling reluctant to take part in this experiment. The participants thought that the aim of the experiment was to test their proficiency in Arabic. The second issue was asking them to write down the words. The participants felt that their hand-writing would not be eligible. Finally, Subject listened only to the filtered recording.

In the main experiment, eighteen native-Arabic speaking listeners were asked to listen to both recordings. This time, and to overcome the first problem above, subjects were assured that the aim of the experiment was to investigate the perception of some consonants in the Libyan dialect. In addition, a new answer-sheet in which the words are typed was created so that the participants would only circle the word they would perceive as right. Having the words typed and ready helped also in eliminating the possibility of choosing high frequency words.

The original recording was also ready to be play after playing the filtered recording as well.

All the participants listened to the filtered recording first and circled the words they thought they perceived on the answer-sheet (See Appendix 3 enclosed). Most of the participants commented that the quality of this recording is confusing, and that the original recording was clearer and more intelligible. However, only a complete analysis of the results can prove that the filtered recording is not as intelligible as the original one.

The results:

When analyzing the results, a new sheet was created (see document 2 enclosed). In this sheet, there are four columns to count every time the /ṣ/ and /s/ were perceived correctly, /ṣ/ became /s/ and the /s/ became /ṣ/. In the answer-sheets, every minimal pair was separately analyzed, the percentage was calculated and the results were compared; filtered vs. original. The same procedure was carried with the answer-sheet of the original recording.

The first minimal pair to analyze was /ṣari:r/ and /sari:r/. Table (1) summarizes the accurate and inaccurate perceptions of /ṣ/ in /ṣari:r/ and /sari:r/ in the filtered and in the original recording.

/ṣari:r/ and /sari:r/	The Original Recording		The Filtered Recording	
	accurate perceptions	Percentage	accurate perceptions	Percentage
/ṣari:r/	50	92.59%	38	70.37%
/sari:r/	53	98.14%	36	66.66%
/ṣari:r/ → /sari:r/	4	7.41%	15	29.63%
/sari:r/ → /ṣari:r/	1	1.86%	19	33.34%

Table (2) A summary of the accurate and the inaccurate perceptions of /ṣ/ and /s/ in /ṣari:r/ and /sari:r/.

While the percentage of accurate perceptions of the /ṣ/ in the original recording was 92.59%, the percentage of accurate perceptions in the filtered recording decreased to 70.37%. In addition, perceiving the unfiltered non-emphatic /s/ decreased as well. In the original recording, this percentage was 98.14%, while in the filtered recording the perception was 66.66%. Intelligibility, as a result has decreased by 31.48%.

The effect of filtering on perception of /s/ was obvious in the same minimal pair. The percentage of perceived /ṣ/ as /s/ in the original recording was 7.41%. As a result of filtering, this percentage increased to 7.41%. The percentage of mistaking /s/ for /ṣ/ increased dramatically from 1.86% in the original recording to 29.63% in the filtered one. Although the intelligibility of /s/ is not the main aim of the current study, simply because /s/ is not an emphatic sound, the percentage is worth mentioning.

The second minimal pair introduced to the participants was /ṣu:ra/ and /su:ra/. Table (2) summarizes the accurate and the inaccurate perceptions of /ṣu:ra/ and /su:ra/ in both recordings

/ṣu:ra/ and /su:ra/	The Original Recording		The Filtered Recording	
	accurate perceptions	Percentage	accurate perceptions	Percentage
/ṣu:ra/	52	96.29%	48	88.88%
/su:ra/	22	40.74%	23	24.59%
/ṣu:ra/ → /su:ra/	3	3.71%	6	11.12%
/su:ra/ → /ṣu:ra/	31	59.26%	31	57.41%

Table (3) A summary of the accurate and the inaccurate perceptions of /ṣ/ and /s/ in /ṣu:ra/ and /su:ra/

The percentage of accurate perception of /ṣ/ in the original recording was 96.29% and its accurate perception in the filtered recoding was 88.88%. In comparison with the previous minimal pair, there is not much influence of filtering on the perception of /ṣ/. When we look at the percentage of /s/, the percentage of accurate perception, which is already not high in the original recording being 40.74, decreased to 24.59%.

While the percentage of perceived /ṣ/ as /s/ in the original recording was 3.71%, this percentage increased to 11.2% in the filtered recording. The percentage of mistaking /s/ for /ṣ/ was 59.26% in the original

recording and 57.41% in the filtered one. It seems that filtering had an effect on the perception of /s/, rather than /ṣ/.

With the emphatic sound in mid-position, three minimal pairs were introduced to the participants. The first minimal pair was /faṣi:la/ and /fasi:la/, /the second one was /qaṣr/,and /qasr/, and the third minimal pair was /waṣama/ and /wasama/. Table (3) shows the accurate and in accurate perceptions of the first pair: /faṣi:la/ and /fasi:la/.

/faṣi:la/ and /fasi:la/	The Original Recording		The Filtered Recording	
	accurate perceptions	Percentage	accurate perceptions	Percentage
/faṣi:la/	49	90.74%	24	44.44%
/fasi:la/	54	100%	34	62.96%
/faṣi:la/ → /fasi:la/	5	9.26%	30	55.56%
/fasi:la/ → /faṣi:la/	--	00%	20	37.04%

Table (4) A summary of the accurate and the inaccurate perceptions of /fa ṣi:la/ and /fasi:la/.

In the original recording, the percentage of perceiving /faṣila/ accurately was 90.74% and the percentage of mistaking the /ṣ/ for /s/ was only 9.26%. This is quite different when compared to 44.44% (the accurate perceptions of /ṣ/ in the filtered recording) and 55.56% (the percentage of perceiving /ṣ/ as /s/ in the filtered recording. As for /s/, all of the participants had no problem distinguishing /s/, as the percentage

of accurate perceptions was 100%. However, in the filtered recording this percentage dropped to 62.96%. Finally, while the percentage of perceived /s/ as /ṣ/ original recording was 0.00%, this percentage increased to 37.04%. It seems that filtering had an effect on the perception of /s/, rather than /ṣ/.

The second minimal pair having /ṣ / in mid position was /qa ṣr/ and /qasr/. Table (4) summarizes the accurate and the inaccurate perceptions of /qaṣr/ and /qasir/.

/qaṣr/ and /qasr/	The Original Recording		The Filtered Recording	
	accurate perceptions	Percentage	accurate perceptions	Percentage
/qaṣr/	46	85.18%	47	87.03%
/qasr/	22	40.74%	16	29.62%
/qaṣr/ → /qasr/	8	14.82%	8	12.97%
/qasr/ → /qaṣr/	32	59.26%	37	70.38%

Table (5) A summary of the accurate and the inaccurate perceptions of /ṣ/ and /s/ in /qaṣr/ and /qasir/.

The accentuate perceptions of /ṣ/ was 85.18% in the original recording, and 870.3% in the filtered recording. The percentage of perceiving /ṣ/ as /s/ was 14.82% in the original recording, and 12.97% in the filtered recording. On the other hand, the percentage of accurate

perception of /s/ was 40.74% in the original recording and 29.62% in the filtered recoding. In addition, the percentage of mistaking /s/ for /ṣ/ was 59.26% in the filtered recording and this percentage increased to 70.38% in the filtered recording.

The pair /waṣama/ and /wasama/ was the third minimal pair having the emphatic and non-emphatic sounds in mid-position and following a glide. Table (5) shows the accurate and the inaccurate perceptions of /waṣama/ and /wasama/.

/waṣama/ and /wasama/	The Original Recording		The Filtered Recording	
	accurate perceptions	Percentage	accurate perceptions	Percentage
/waṣama/	53	98.14%	28	51.85%
/wasama/	49	90.74%	44	81.48%
/waṣama/ → /wasama/	2	1.86%	26	48.15%
/wasama/ → /waṣama/	4	9.26%	10	18.52%

Table (6) A summary of the accurate and the inaccurate perceptions of /ṣ/ and /s/ in /waṣama/ and /wasama/.

While the percentage of accurate perceptions of /ṣ/ in the original recording was 98.14%, the percentage decreased to 51.85% in the filtered recording. These results show a clear influence of filtering on the perception of /ṣ/. Further evidence in support of this influence comes from the instances of perceiving /ṣ/ as /s/. In the original

recording, this percentage was 1.86%, but it increased to 48.15% in the filtered recording

Filtering did not have such influence on the perception of /s/. In the original recording, the percentage of accurate perceptions was 90.74%, and this percentage decreased to 81.48% in the filtered recording. The difference in the percentage of mistaking /s/ for /ṣ/ in the two recordings was not big too. It was 9.26% in the original recording and 18.52% in the filtered one.

The last minimal pair introduced was /haraṣa/ and /harasa/. Table (6) shows the accurate and the inaccurate perceptions of /ħaraṣa/ and /ħarasa/.

/ħaraṣa/ and /ħarasa/	The Original Recording		The Filtered Recording	
	accurate perceptions	Percentage	accurate perceptions	Percentage
/ħaraṣa/	42	77.77%	28	51.85%
/ħarasa/	52	96.29%	38	70.37%
/ħaraṣa/ → /ħarasa/	12	22.23%	26	48.15%
/ħarasa/ → /ħaraṣa/	2	3.71%	16	29.63%

Table (7) The accurate and the inaccurate perceptions of /ṣ/ and /s/ in /ħaraṣa/ and /ħarasa/.

The reason behind choosing this pair is to see if the initial /ħ/ would be carried through the vowel and increase the intelligibility of the emphatic sound, and decrease the intelligibility of the non-emphatic sound.

While the percentage of accurate perceptions of /ṣ/ in the original recording was 77.77%, the percentage decreased to 51.85% in the filtered recording. Regarding /s/, the percentage decreased from 96.29% in the original recording to 70.37% in the filtered one. This shows that filtering had an effect on the perception of both /ṣ/ and /s/. In the same manner, mistaking /ṣ/ for /s/ increased from 22.23% in the original recording, to 48.15% in the original recording. With respect to the inaccurate perceptions of /s/, (mistaking it for /ṣ/), the percentage dramatically increased from 3.71% in the original recording. to 29.63% in the filtered recording.

Discussion of the results:

In /ṣari:r/ and /sari:r/ , the accurate perception of /ṣ/ decreased by 22.22% (and mistaking it for the non-emphatic sibilant decreased by almost the same percentage). This proves that /ṣ/ in the original recording was more intelligible. Further evidence in support of the influence of filtering on the perception of the recording is the percentage of accurate perception of /s/. This accurate perception (although it is not the main focus in this project, the percentage is worth mentioning) has decreased by 31.48%. In /ṣu:ra/ and /su:ra/, it seems that the back vowel /u:/ had a great influence on the perception of /ṣ/ and /s/ in this pair. The percentage of accurate perceptions of /ṣ/, which was high in the original recording, decreased by only 7.41% when the participants listened to the filtered recording. The same vowel effect can be seen on the non-emphatic sibilant where the percentage of accurate perceptions decreased by only 16.15%.

Discussing the results of the three minimal pairs containing /ṣ/ and /s/ in mid-position is quite interesting. In /faṣi:la/, the accurate perception decreased by 46.03%. It is, by far, the highest percentage among other minimal pairs. In addition, there was a decrease of the percentage of accurate perceptions of /s/ from 100% in the original recording to 62.96. This proves that filtering has a big influence on the perception of this pair. What justifies the perception of /qaṣr/ and /qasr/

is the influence of /q/ which is a back consonant on the non-emphatic sound/s/. The accurate perceptions of /s/ did not decrease that much, and the high percentage of mistaking it for /ṣ/ is the proof.

On the other hand, the accurate perceptions of /ṣ/, which are high from the beginning, increased only by 1.85%. This proves that having a back consonant in the same word can affect perception. In /waṣama/ and /wasama/, not having another back consonant, or a back vowel, decreased the number of accurate perceptions in the original recording by 46.29%. There was not such a decrease in the accurate perceptions of /s/, because of the lack of neighbouring back consonants or back vowels. In fact, the decrease of its intelligibility is only 9.26%. In the last minimal pair, it seems that the /ħ/ sound had a considerable influence to play on perception of both /ṣ/ and /s/. The percentage of accurate perceptions of /ṣ/ and /s/ decreased by (the same percentage by chance) 25.92% in both. This indicates that the original recording was perceived as more intelligible.

Conclusion:

In conclusion, emphatic sounds, their production and their acoustic energy were discussed in this paper. Although their classification is widely debated, the mechanism involved in their production and their acoustic energy is clear-cut. The constriction of the tongue, caused by the tongue being retracted towards the pharynx is what makes these sounds emphatic. This constriction affects the vowel formants by raising F1 and lowering F2. The result of filtering the second formant

of the vowels in the vicinity of emphatic sounds played a role in rating intelligibility. This effect was mostly seen in words containing only one emphatic sound and front vowels like /faṣi:la/. Little influence has been noticed in /qaṣr/, because of the /q/ sound. The word /ṣu:ra/ was not very intelligible because of the back vowel /u:/. The percentage of perceiving /ṣ/ as /s/ was 34.25%. There was also an emphasizing of the non-emphatic sound /s/. This was mostly seen in /qaṣr/, because of the /q/ sound, and less in /waṣama/, because it contains only one emphatic sound, and no back vowels. The percentage of placing emphasis on /s/ was 41.04%. Although, the filter affected perception and intelligibility, it is obvious that it worked more effectively on words containing two emphatic sounds or back vowels. For further research, choosing two groups of minimal pairs with one and two emphatic sounds, and changing the filter specifications to reject more frequencies will conclude the influence of two emphatic sounds, in the same word, on intelligibility and will determine which frequencies are more vital in ensuring intelligibility of emphatic sound.

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