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Production of gutturals by non-native speakers of Arabic

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ABSTRACT

This paper investigates the production of Arabic gutturals by native (NSs) and non-native speakers (NNSs) of Arabic. A total of 40 participants, 20 NSs and 20 NNSs were recruited. 240 tokens were collected using two major methods: free speech and nonsense word testing. Using PRAAT software (version 6.1.01), the tokens were analyzed acoustically to measure F1 and F2 and to signal the (non)significance of the difference between the target groups and auditorily to rate gutturals' production accuracy by NNSs. F1 and F2 of the vowels neighbouring the gutturals were normalized using the speaker extrinsic Labov ANAE method (NORM version 1.1) to eliminate the effects of gender and age. The study demonstrates some important findings: in terms of quality, the F1-F2 approximation varies by nativeness in that NNSs were unable to make enough coarticulatory effects associated with Arabic gutturals. This result indicates that NNSs do not make a sufficient primary constriction in the posterior regions of the vocal tract. Relying on auditory judgments of accuracy, the most accurately produced gutturals by NNSs were the voiceless glottal fricative /h/ followed by the voiceless glottal plosive /ʔ/, and the lowest ranked gutturals were the voiced velar fricative /ɣ/ and the voiced pharyngeal fricative /ʕ/. The study concludes that non-temporal cues especially F1 and F2 are essential correlates to Arabic gutturals' production. Because such factors are language-specific, they should be taken into consideration in the teaching of Arabic as a second/foreign language.

Keywords: Arabic, first language (L1); gutturals; second language (L2); production accuracy

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INTRODUCTION

Gutturals (from the Latin for throat, *ḥuruuf al-ḥalq* 'literally, letters of throat' in the early Arabic grammar) refer to the sounds produced with a primary constriction in the posterior regions of the vocal tract (McCarthy, 1991, p. 63). These sounds are produced with certain vocal tract gestures and movements corresponding to distinctive sound-producing states formed by specific air pressure and air flow information, a pattern that McCarthy (1991, 1994) describes as *orosensory*. Arabic has six guttural consonants: the laryngeal /ʔ/ and /h/ (with a fully constricted glottis), the pharyngeal /ħ/ and /ʕ/ (with a retracted tongue root back, the anterior wall of the pharynx, and the epiglottis towards the posterior wall of the pharynx), and as a non-primary feature, the uvular /x/ and /ɣ/ (with a retracted tongue dorsum accompanied with a raised and flattened velum in the case of /x/, and a lowered velum in the case of /ɣ/) (Bin-Muqbil, 2006; Mashaqba, 2015; Watson, 2002).[i] All these phonemes may occur word-initially, medially and finally in Arabic, as in Table 1.

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Table 1
Arabic guttural consonants word-initially, word-medially, and word-finally

_word-initially		word-medially		word-finally		
/ʔ/	/ʔasad/	lion	/saʔal/	asked	/nabaʔ/	news
/h/	/hadaf/	goal	/ðahab/	gold	/muntazah/	park
/ħ/	/ħiṣa:n/	horse	/naħla/	bee	/miṣba:ħ/	lamp
/ʕ/	/ʕalam/	flag	/θaʕlab/	fox	/ḍifdaʕ/	frog
/x/	/xaru:f/	lamb	/naxla/	palm	/maṭbax/	kitchen
/ɣ/	/ɣaza:l/	gazelle	/raġwa/	foam	/fa:riġ/	empty

According to the UPSID1 data (Maddieson, 2009), of 317 world languages, very few have sounds with a pharyngeal primary articulation. For instance, /ʕ/ is found in only eight languages including Arabic, the voiceless pharyngeal /ħ/ in 13 languages, and 54 languages including Arabic contain the uvulars /q, ɣ, x/ (Elgendy, 2001). Given that guttural sounds exhibit a significant functional load through the high frequently occurrence of phonemic contrasts within the guttural class and among other sound classes in Arabic, these sounds are considered noticeably challenging and the most problematic to a variety of L2 learners.

Learning guttural sounds has been a challenging task in Arabic phonological development as a second/foreign language (Eads et al., 2018). This can be attributed to the complex articulatory attributes (primary constriction in the posterior regions of the vocal tract) which results in specific acoustic correlates (raising F1 and lowering F2 of adjacent vowels) of guttural sounds in Arabic (Zawaydeh, 1999). Hence, knowing the nature of Arabic gutturals properly is very essential to NNSs as this would signify the most important ways to develop the learnability of such sounds. Additionally, where speakers may not share the same language aspects, interaction may involve misunderstanding or ambiguity. Mispronunciation of any of these phonemes creates a linguistic problem, for example, if a NNS asked for /raɣwa/ 'foam' and was not able to pronounce the guttural /ɣ/ correctly and pronounce it, for instance, as [x] [raxwa] instead, this will result in a new word, because [raxwa] means 'loose', which therefore may result in a communication breakdown, if the pragmatic context does not help clarify the intended meaning. Hence, improving the accuracy rate and production of meaningful vocabulary are very influential factors in the development of forging learners' 'global intelligibility' (Moedjito et al., 2019).

Recent work, although a small amount, has focused on the challenges encountering foreign learners of Arabic in terms of gutturals articulation (e.g., Al-Mahmoud, 2005; Eads, et al., 2018). However, more research is needed to investigate the acoustic properties of gutturals so that we get a better understanding of the nature of such a group of sounds. Acoustic information/correlates of gutturals (e.g., raising F1 and lowering F2 of the vowels in the vicinity of gutturals) will experimentally establish the acoustic cues of guttural sounds and identify the problems that NNSs of Arabic face in producing gutturals, instead of relying only on an impressionistic approach. By relying on a semi-automated tool, we are limiting the linguistic variant differences and focus on the linguistic parameters. Consequently, one major purpose of this research is to acoustically examine the Arabic gutturals by NSs and NNSs of Arabic. Moreover, literature lacks studies that show the perception/auditory specification of gutturals by NNSs of Arabic. The current study also evaluates an auditory measure of the correctness that L2 participants perform, highlighting the most and least accurately produced sounds. This will provide language teachers with important information that can improve production and perception efficiency. It will also help language teachers in understanding the problem of incorrect production when dealing with NNSs who might require a suitable remedial measure in the future.

To meet the goals, this work overviews the articulatory and acoustic attributes of Arabic gutturals, followed by the theoretical background on the importance of L2 learning. Given that the acoustic qualities are a reflection of the articulatory attributes of speech sounds, the present work measures the basic acoustic tenets related to the guttural sounds articulation by NNSs, namely F1 and F2 of vowels adjacent to guttural sounds, and compare them with the results obtained from NSs. Guttural sounds produced by NNSs were also auditorily rated in terms of accuracy. After discussing the results, we conclude the study with some useful remarks and implications.

Articulatory-acoustic Correlates of Arabic Gutturals

The (co)articulatory, acoustic, and perceptual characteristics of gutturals have always been controversial. Being aware that the place feature [guttural] stands for a zone of articulation (larynx, pharynx, and uvular), rather than one articulator (Watson, 2002, p. 38), still do not agree on whether or not to phonologically consider gutturals as an active natural class, i.e. part of the human's innate linguistic competence (Sylak-Glassman, 2014, p. 3). Based on place of articulation, McCarthy (1991) elaborates that gutturals are a natural class that can be defined by their distinctive orosensory pattern, encoding specific vocal tract gestures and movements. McCarthy (1994) has further shown that Semitic languages do possess a guttural natural class, identifying them as pharyngeals. However, Sylak-Glassman (2014, p. 11) argues that "gutturals, rather than being innate, emerge in specific languages from phonological processes and distributional constraints that are conditioned by phonetic properties". To decide, the group of sounds exclusively must minimally satisfy one of these criteria: the group of sounds complementarily undergo (or at least trigger) a particular phonological process, or form 'a static distributional relation' (Mielke, 2008, p. 13 as cited in Sylak-Glassman, 2014, p. 1). Similarly, gutturals (the so-called root sounds/post-velar) may form an active natural class since they constitute a sound pattern which involves lowering the adjacent vowel ((to /a/) (McCarthy, 1994; Sylak-Glassman, 2014, p. 2). However, the ability of Arabic gutturals to scheme under one unified phonological matrix that suffices to the requirements of the basics of the articulatory theory is under evaluation since the three Arabic guttural subclasses are articulated at three different places of articulations within the pharyngeal region (cf. McCarthy, 1994). Further, true articulation of uvulars does not consistently involve [-high] since it involves a raised tongue. Against the previous literature, McCarthy (1994) insists that pharyngeals and laryngeals do not perform any of the [back] and [low] features simply because their articulation properties never involve the tongue body movement as an active articulator.

On the other hand, based on acoustic experiments, Zawaydeh (1999) added emphatics[ii] (in addition to uvulars, pharyngeals, and laryngeals) as a fourth subclass of gutturals. These four subclasses share one feature specification: they involve a constriction in the back of the vocal tract. On the basis that pharynx is an active articulator for the production of gutturals (excluding laryngeals), she suggests a new distinctive feature called [Retracted Tongue Back].[iii] In generative phonology, many systematic observations[iv] on the behaviour of the three subclasses of gutturals (uvulars, pharyngeals, and laryngeals) authorize some researchers (including McCarthy, 1991, 1994; Watson 2002, among others) to phonologically propose guttural sounds under one natural class. This natural class is recognized as [guttural] in Watson (2002), and [pharyngeal] in McCarthy (1991, 1994).

Acoustically, Arabic gutturals have been characterized as having relatively high F1 values in the adjacent vowels (McCarthy, 1991; Shar, 2004, 2012; Watson 2002). McCarthy (1991) connected the production of gutturals in the posterior region of the vocal tract as the driving force resulting in high F1 values. Al-Tamimi and Heselwood (2011) reported two major results regarding Arabic gutturals: the first is having F2 values that are lower than the values for prototypical non-guttural sounds; and the second is having F1 values that are higher than those of the prototypical non-guttural sounds. Although these two occurrences are simultaneous, the high F1 values are more significant. Shar (2004) agrees with Al-Tamimi and Heselwood's conclusions, stating that gutturals have high F1 (the higher F1 frequency, the lower the gesture) and low F2 (which relates to the backness dimension whereby back sounds have lower F2 values). Such acoustic characteristics have an important effect on the neighbouring vowel, given that the acoustic correlates are a direct reflection of the articulatory gestures. That is, spread from a guttural oral sound tends to result in centralization of [dorsal] vowels and both lowering and retraction of [guttural] vowels (Watson, 2002, p. 46).

Theoretical Background on L2 Learning

Learners of a foreign language may fail to communicate effectively with L1 NSs because of their foreign accent, intelligibility problems, or misproduction of certain segmental or prosodic elements (e.g., Abu Guba et al., 2021; Al-Mahmoud, 2005, 2020; Huneety et al., 2020; Mahmoodi & Zekrati, 2016; Sao Bui, 2016). These problems have several causes, including critical period effects (e.g., Hartshorne et al., 2018), non-biological factors (such as length of residence and exposure to L2) (Flege & Liu, 2001), and the relationship between speech sounds production and perception of L2 (e.g., Huneety et al., 2020; Yeon, 2003).

Examining the perception and production of linguistic entities of L2 learners, some researchers agree that some NNSs are unable to produce native-like linguistic patterns related to pronunciation, i.e. production of phonetic and phonological structures as opposed to other linguistic skills such as syntax and morphology (Al-Mahmoud, 2005). Scovel (1990) states that the acquisition of pronunciation patterns is limited to a critical period, approximately at age 10, which is due to the loss of the neuro-plasticity and the completion of the lateralization process. He explains why the critical period should be confined to the acquisition of sounds but not to other linguistic skills such as syntax, semantics and morphology. He points out that neuro-plasticity is essential in the learning of phonology but not in other linguistic aspects because "pronunciation is the only part of language which is directly physical and which demands neuromuscular programming"; in contrast, other skills are cognitive or perceptual (Scovel, 1990, p. 62).

Scholars debate whether it is the perception or the production of linguistic items that is the key to determining the level of nativeness reached by an L2 learner. As to production, some argue that it is possible for an L2 to reach an L1 level, while others declare it impossible, no matter how much training is given in producing the target linguistic items

(Bongaerts et al., 1997; Moyer, 1999). Unlike the acquisition of an L1, which can be achieved through mere exposure to primary linguistic input, Saito et al. (2020) further believe that learning an L2 after puberty is dependent on formal auditory processing that determines proficiency scores. Thus, it is important to compare the production of Arabic gutturals by NNSs and NSs, and specifically at an age beyond the critical period. This study is significant because gutturals are one of most distinctive classes that distinguish Arabic from many other languages, and which are very important in the field of teaching Arabic to non-Arabs. After acquisition takes place (typically before the critical period), acquisition/mastery of gutturals becomes extremely difficult; hence, experimental acoustic measurements and auditory ratings feedback would be very helpful for language instructors to address the NNSs pronunciation errors. So far, no study has satisfactorily addressed the acquisition of Arabic gutturals by NNSs. To this end, the research gap lies in the insufficient acoustic data for non-native production of gutturals in Arabic. The present experimental study investigates gutturals' production acoustically and auditorily to contribute to the research pool of teaching/learning Arabic as a foreign language.

To this end, this study hypothesizes that the production of gutturals differs significantly between NSs and NNSs acoustically, and that NNSs of Arabic will struggle to produce gutturals in an adult-like fashion (cf. the concluding remarks).

METHOD

A total of 40 participants were recruited (ten females and ten males in each of the two groups) through direct contact with researchers in the department of Arabic Linguistics at the University of Jordan. The average age was 23.25 (min=18 max=28) for NNSs, and 21.7 (min=19 max=25) for NSs. When we recruited the participants, none of these participants knew a first/second language that contains ALL Arabic gutturals or even similar guttural sounds. Their languages might have 1-2 gutturals but not all of them. For further details about the participants, see the metadata sheet in the appendix. All of the participants were given an information sheet outlining the research aims and objectives, and written consent was obtained from those who agreed to participate. At the time of recording, it was proved that all the NNSs received prior pronunciation instruction under similar conditions, curricula and teachers; they had a minimum of one-year exposure to Arabic post-puberty; that is, they could not acquire the target language with native competence in their L2 phonology (e.g., Fantazi, 2003). A speech specialist ensured that none of the participants in both groups had any speech or hearing impairment. The 20 native participants originated from Amman, spoke urban Jordanian Arabic dialect, were proficient in Standard Arabic, and shared the same sociolinguistic background. The average age of the NNSs was 23.25 (range 18 to 28), and of the native participants 21.7 (19 to 25). Eight languages were tagged as L1 of the NNSs: Spanish (2 participants), Albanian (3 participants), Chinese (6 participants), Kapampangan (2 participants), French (2 participants), Indonesian (1 participant), Kazakh (3 participants), and Malaysian (1 participant); for details, see the appendix.

Two major methods were used to collect the data. The first was free speech task, in which participants were engaged in a 1-2-minute conversation that included general questions about their linguistic background. This method ensures that natural speech is produced. Eliciting naturally occurring data contributes to normal production where phonological repair processes are attested. This procedure also limits the influence of speech memory (that repetition tasks use) which influences production and can cause bias in results. In the second, participants were asked to pronounce a set of nonsense words that contain guttural consonants with an **aGa** VCV template within a sentence frame of *say the word aGa twice* for each guttural consonant (G=guttural). This method was used to obtain the guttural sounds in the same phonetic environment to allow acoustic comparisons. Recall that acoustic measurements, on which this study heavily depends, require compatible environments neighbouring the gutturals so that F1 and F2 measurements are more reliable and valid (see Mashaqba, et al., 2022). A total of 240 tokens were analyzed by the authors acoustically using PRAAT Software (version 6.1.01). Average F1 and F2 readings were measured for each produced token at the steady states and transition stages. Recall that a vowel formant, which is determined by the shape and length of the vocal tract, refers to 'a group of overtones corresponding to a resonating frequency of the air in the vocal tract' (Ladefoged & Johnson, 2015). F1 is inversely proportional to vowel height; the higher F1 frequency, the lower the vowel. F2 relates to the backness dimension whereby front vowels have higher F2 frequencies than back vowels.

It is well-known that vowel formants differ as a function of gender and/or age because of the differences in vocal tract sizes (Maurer et al., 2015). Direct sex/gender spectral (formant) comparisons are not useful, and can be meaningless, without performing normalization in order to control for the effect of gender and age (the vocal tract biological factor: female vs. male, children vs. adults) (cf. Abu Guba et al., 2022). Thus, to eliminate variation caused by physiological differences (i.e. differences in mouth sizes) raw formant frequencies of all vowels for all speakers were normalized using the speaker extrinsic Labov ANAE method available within the online vowel normalization suite, NORM version 1.1 (Thomas & Kendall, 2007). This method is able to account for anatomical and physiological variation between speakers while it preserves sociolinguistic differences (Mashaqba et al., 2021; Thomas & Kendall, 2007). To estimate the reliability of F1 and F2 measurements, 24 tokens were randomly selected and re-analyzed by the first author following the same procedure explained above. The correlations between the retested tokens and the original measurements were above 97%, and thus the measurements were judged reliable. A two-tailed Mann Whitney U test was performed to account for statistical differences between male/female and native/non-native productions of Arabic gutturals. This nonparametric test was selected because the sample size is not large enough and the data is not normally distributed. All the tokens of guttural nonsense words produced by the NNSs were auditorily judged/rated by two native Arabic-speaking linguists on a three-point scale of correctness: (1 = correct, 2 = partially correct, 3 = incorrect).

FINDINGS AND DISCUSSION

NSs vs. NNSs Production of Arabic Gutturals

This section deals with the acoustic differences between NSs and NNSs in an attempt to understand the effects of L2 learning on homogeneous-gender groups. The key feature tested in this experiment is the coarticulatory impact of gutturals on the vowel formants F1 and F2 of adjacent vowels. Table 2 summaries the mean F1 and F2 measurements of the vowels before and after the target guttural sounds for NSs and NNSs. The mean values for F1 and F2 are statistically significant for the vowels adjacent to the guttural sounds /x, ɣ, ħ, ʕ, ʔ/, but not /h/.

Table 2
Mean F1 and F2 of the Vowels Before and After Gutturals for NSs and NNSs

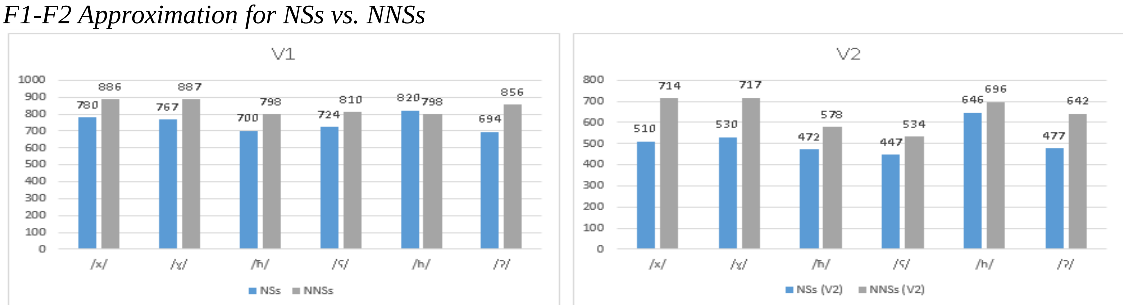
	V1				Mann Whitney U Test		V2				Mann Whitney U Test	
	NSs		NNSs		Test-F1	Test-F2	NSs		NNSs		Test-F1	Test-F2
	F1	F2	F1	F2			F1	F2	F1	F2		
/x/	692	1472	785	1671	>.05	>.05	705	1215	758	1472	>.05	>.05
/ɣ/	738	1505	798	1685	>.05	>.05	712	1242	768	1485	>.05	>.05
/ħ/	810	1510	857	1646	>.05	>.05	753	1225	840	1418	>.05	>.05
/ʕ/	794	1518	845	1655	>.05	>.05	771	1218	891	1425	>.05	>.05
/h/	760	1580	786	1584	*<.05	*<.05	726	1372	702	1398	*<.05	*<.05
/ʔ/	792	1486	835	1691	>.05	>.05	772	1249	872	1514	>.05	>.05

- *marks insignificant difference between the mean values of NSs and NNSs
- significance level, α = .05

The p-values of the calculated Mann Whitney U test are lower than the alpha significance level (p-value < .05). That is, the F1 and F2 values of vowels in the vicinity of guttural sounds among NNSs differ statistically from those of NSs except for the guttural /h/ environment (p-value ≥ .05). Intriguingly, all NNSs have registered high F1 transitions, which means that they try to open the oral tract a little more than the typical gestures when producing the target guttural (see sample spectrograms in the Appendix).

Recall that the production of guttural sounds is typically coarticulated with F1 raising and F2 lowering of the vowels adjacent to gutturals. This feature entails that vowels in the context of guttural sounds would be more compact as reflected in F1-F2 approximation. Taking the mean values of each vowel neighbouring the guttural sound, we found that the F1-F2 approximation was consistently more active by NSs for vowels adjacent to guttural sounds except for that of the guttural /h/. Nevertheless, NNSs demonstrated less F1-F2 approximation values in the vowels preceding and following the guttural sounds (see Figure 1 and sample spectrograms in the Appendix).

Figure 1
F1-F2 Approximation for NSs vs. NNSs



More intriguingly, F1-F2 approximation effect made by NSs was stronger in the vowels after the gutturals in comparison with the vowels preceding the gutturals, a new finding that was never reported before in the previous literature to the best of our knowledge. This result may imply that guttural spreads more effectively rightward than leftward (see a sample of spectrograms of the native and non-native participants in the Appendix). This finding may be accounted for by the notion that the configuration for the production of the sound or the gestural score in the production of these guttural sounds persists into the following sound because it is more difficult or it takes more time to get back to the gestural score of the vowel.

In addition, the figure shows that NNSs were not able to make a significant rate of F1-F2 approximation (although they reported a high F1), which indicates that they were not able to make enough coarticulatory effects and thus do not produce Arabic gutturals as back as required because they do not make a sufficient primary constriction in the posterior regions of the vocal tract (see a sample of spectrograms of the native and non-native participants in the Appendix) Similar results were reported for the English learners of Arabic (Al-Mahmoud, 2005; Eads et al., 2018) and the Finnish learners of Arabic (Bedir, 2019). The clear differences in the production of the five guttural sounds may be related to the phonetic properties of these sounds in Arabic, especially /ħ/ and /ʕ/ whose production was quite hard. Similar results were obtained by Bedir (2019) where Finnish learners of Arabic found the voiceless pharyngeal /ħ/ and the voiced pharyngeal /ʕ/ the most difficult guttural consonants in their production. This difficulty is predicted because not only the retraction of the tongue root affects the production of the pharyngeals, but also the anterior wall of the pharynx, and the epiglottis towards the posterior wall of the pharynx are involved in (see Bin-Muqbil, 2006). Moreover, the fact that Arabic gutturals are among the least frequently occurring consonants in Arabic (Al-Mahmoud, 2020, endnote 1) makes the acquisition of these sounds more challenging, as pronunciation acquisition requires a great deal of exposure to the language in question. Noteworthy, some participants completely substitute guttural consonants with other guttural or back consonants. The most frequent and consistent cases are: /ʕ/ > [ʔ], /ħ/ > [h] or [x], /x/ > [h] or [k], /ɣ/ > [g] (see a sample of spectrograms of the native and non-native participants in the Appendix).

Although beyond the scope of this study, we have measured some tokens in terms of duration (word duration, consonant duration) and it was found that NNSs produced durationally longer guttural consonants with a mean of (.12 s.), compared to the NSs' (.093 s.). This may be due to the fact that some NNSs produced geminate/long guttural consonants while trying to pronounce the target consonant, making the mean duration of these consonants longer in duration. Thus, the mean value of consonant duration in NNSs was found to be longer than NSs'. Recall that males are 'believed' to produce faster speech rate (i.e., speak faster) than females do (e.g., Fitzsimons et al., 2001; Pépiot, 2014, for similar results). However, experimental findings are inconclusive in this regard (cf. Simpson & Ericsdotter, 2003, for insignificant cross-gender difference). This is even suggested by the results of this experiment (in the pilot study we carried out) for both language groups, in which female NSs, almost consistently, showed longer mean temporal measurements in terms of word duration, guttural sound duration, and following vowel duration (preceding vowel duration is reported to show no significance), thus indicating a slower speech rate than male speakers. For NNSs, women consistently produced longer word, consonant and vowel durations. The point we are trying to make here is that the difference of consonant/vowel duration may possibly be independent of the production of gutturals. Taking into consideration that duration is a key attribute of the production of geminate gutturals, they are not a main target of this work. Instead, it might be a general gender-related pattern.

Ratings of Production Accuracy of Gutturals by NNSs

All the tokens of NNSs were rated auditorily by two native Arabic-speaking linguists to evaluate the correctness of the production of Arabic gutturals, measured on a three-point scale (1 = correct, 2 = partially correct, 3 = incorrect) and the averages from the two reviewers were calculated.

Table 3 summarizes the average ratings and the ranking of each guttural sound produced by NNSs of Arabic; the closer the average to 1, the greater the level of correctness. (cf. the Appendix for the detailed scores for each NNS).

Table 3 shows that the most accurately produced guttural sound is the voiceless glottal fricative /h/. This result may be attributed to the notion that participants' L1 contains that sound in their phonological system

Table 3

Average Ratings and the Ranking of Each Guttural Sound Produced by the 20 NNSs

Word	Average/Females	Average/Males	Rank
aha	1.45	1.15	1
aʔa	1.6	1.25	2
aħa	1.7	1.55	3
axa	1.9	1.6	4
aɣa	2	1.9	5
aʕa	2.1	2.1	6

The second highest ranked guttural sound is the voiceless glottal stop /ʔ/, followed by the voiceless pharyngeal fricative /ħ/, and then the voiceless velar fricative /x/. The voiced velar fricative /ɣ/ and the voiced pharyngeal fricative /ʕ/ were ranked the least accurately produced, respectively. In line with Al-Mahmoud, (2005), Bedir (2019), Eads et al. (2018), this research reveals that NNSs have different abilities in producing Arabic gutturals, but the pharyngeals /ħ, ʕ/ and uvular /x, ɣ/ are more problematic than the laryngeal /h, ʔ/ where such sounds do not exist in most of the L1 languages of NNSs. Difference in the reported results may be attributed to L1 interference as the six gutturals do not occur in their L1 equally (see Table 4). Some research found that accuracy of production is correlated with occurrence frequency (Amayreh, et al., 1999; Mashaqba, et al., 2022). Pharyngeals /ħ, ʕ/ and uvulars /x, ɣ/ were found not to occur as frequently as the laryngeals /ʔ, h/. Thus, responses from participants vary: some have a more accurate production than others because their languages involve some sounds that are near in place/manner of articulation to the Arabic equivalents, e.g., the liquid uvular /ʁ/ in French (Walker, 2001), the velar /x/ in Spanish (Macpherson, 1975) and in Chinese (Hua & Dodd, 2000), and the secondary laryngeal /x/ and /ɣ/ in Malayan (Phoon, et al., 2014); see Table 4. The phonetic/acoustic properties of these sounds in Arabic are different because they are pharyngealized. In the other languages, e.g., Spanish and French, they are not pharyngealized (they do not involve a secondary coarticulatory feature of [pharyngealization].

Table 4

Distribution of Guttural Consonants Inventory in the NNSs Languages

Language	velar	uvular	Pharyngeal	laryngeal	
Spanish	x	-	-	h	(Macpherson, 1975)
Albanian	-	-	-	h	(Klippenstein, 2010)
Chinese	x	-	-	-	(Hua & Dodd, 2000)
Kapampangan	-	-	-	ʔ	(Forman, 2019)
French	-	ʁ (liquid)	-	-	(Walker, 2001)
Indonesian	-	-	-	h, ʔ	(Soderberg & Olson, 2008)
Kazakh	-	x, ɣ	-	-	(McCollum & Chen, 2021)
Malaysian	h	-	-	ʔ, (x), (ɣ)	(Phoon, et al., 2014)

( ) secondary consonant

Recall that the distribution of gutturals into three subclasses (uvulars, pharyngeals, and laryngeals) which involve an active participation of three different places (uvular, pharynx, and glottis) would constitute a challenge to capture the typical articulatory traits by NNSs (see Bin-Muqbil 2006). The absence of such articulatory gestures implies the absence of the cognitive model by which NNSs test their perceptive and articulatory abilities concerning the L2 sounds. This was supported by the acoustic data which confirm that the secondary articulatory attributes in Arabic gutturals are fundamentally different from the articulations of all other sound subclasses (Al-Mahmoud, 2005; Bedir, 2019). In terms of articulation, difficulty in producing /ħ/, /x/, /ɣ/ and /ʕ/ may be ascribed to the notion that NNSs do not retract their tongue-root back sufficiently while pronouncing the pharyngeals /ħ/ and /ʕ/, and do not have enough retracted tongue dorsum in the case of the uvular /x/ and /ɣ/. This could be a result of the fact that pharyngeal and uvular places are not active articulators in the NNSs' L1s. Table 4 shows that none of the eight languages contain the pharyngeal consonants, and six languages do not contain the uvular consonants. On the other hand, the voiceless laryngeal fricative /h/ and the laryngeal glottal stop /ʔ/ were the most correctly pronounced gutturals. In addition to their occurrence in some of the participants L1s sound system, their high accuracy of production would be most probably because these laryngeals are the least guttural sounds associated with particular transitions in adjacent vowels because they do not involve active tongue root constriction (cf. Bin-Muqbil, 2006, p. 204).

CONCLUSION

This paper presents the findings of an investigation into the phonological differences in the production of Arabic gutturals as produced by native and non-native females and males. The three-route analysis by statistical, acoustic and auditory investigation produced three major results. First, the analysis proved that the production of Arabic gutturals by NSs and NNSs differed significantly in formant frequencies approximation of the vowels neighbouring gutturals. Except for the voiceless glottal fricative /h/, the results confirm that the NNSs do not give any active and correct production of any guttural consonants.

Based on the rating of the tokens produced by NNSs, the most accurately produced guttural sound is the voiceless glottal fricative /h/; the second highest is the voiceless glottal stop /ʔ/, followed by the voiceless pharyngeal fricative /ħ/, the voiceless uvular fricative /x/, and the voiced uvular fricative /ɣ/, respectively. The lowest ranked is the voiced pharyngeal fricative /ʕ/. The mispronunciation of certain gutturals or substitution of other sounds was due to the coarticulatory attributes that gutturals have, the lack of guttural sounds in the phonemic inventory of the participants' L1, and lack in exposure to Arabic-speaking environment.

Future studies on guttural consonants by NNSs should examine L1 background separately. Future studies also should take into consideration control over the NNSs L2 and L3. One of the limitations of the study is that we did not explore the ability of participants to produce a correct guttural sound while his/her L1 lacks that sound in its phonological system, yet, his/her second or third language may have it. This aim is part of a bigger phonological question: is the brain able to isolate the multiple phonological systems a multi-lingual person has, or does it combine them?

Although the study has conducted a thorough analysis of the available data, there were other limitations that obstructed the processes. First, it has been statistically impossible to test the statistical significance between the native and non-native vowel formants in guttural contexts. This is due to the insufficient amount of data measurements to run the two-tailed, equal variances Mann Whitney U test which leads to an unreliable statistical testing. Second, the recruited data was insufficient to reflect a scientific answer of the aforementioned aim as it has not been attested that the participant's L1 has lacked a target guttural sound in its system, yet had that guttural sound in his/her second or third language's phonological system. Further studies should focus on recruiting more multi-lingual participants with special emphasis on their second and third language in an attempt to answer whether the brain manages to isolate or combine the multiple phonological systems a multi-lingual person has. In other words, if a participant's L1 does not have the sound (X) but his/her L2 or third language has (X), in this case, one should explore whether he/she is able to produce (X) correctly i.e. acoustically similar to the native readings.

Finally, pedagogically improving the pronunciation of words with guttural sounds definitely leads to acceptable communication skills in conveying meaning as a component of language competence. As teaching pronunciation is a major goal of global intelligibility (cf. Moedjito et al., 2019), the study can provide Arabic learners, instructors and developers of instructional materials with some theoretical and pedagogical implications for more effective teaching of such sounds, so that the Arabic leaners may produce more intelligible utterances (see the Findings and Discussion Section). Instructors are recommended to prepare videos and drawings explaining the mechanisms of gutturals articulation in the oral tract, and report examples about the possible mistakes they might make, with special focus on minimal pair words. Videos that show the tongue height and backness in the mouth would be helpful to show the learners how F1 and F2 should be approximated in the production of gutturals. They are also recommended to give NNSs special training (e.g., using tongue depressor, clearing the throat/spluttering, video recordings of the trainees) that stimulate the articulators (muscles) involved in the articulation of the guttural sounds. In particular, learners should be trained on retracting their tongue-root in a sufficient manner to produce the pharyngeals correctly. Finally, phonetic skills should be integrated with other linguistic skills when teaching Arabic gutturals.

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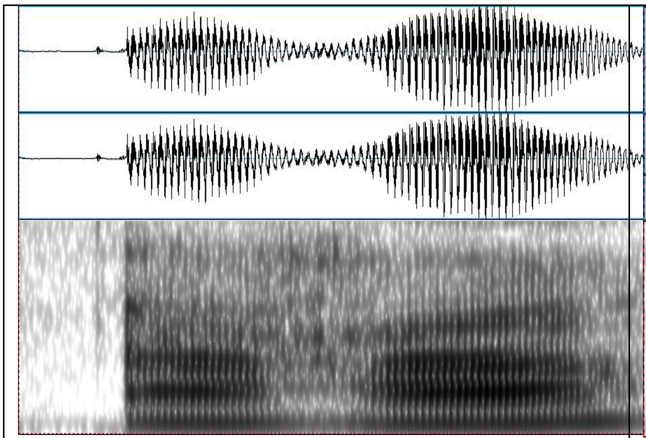
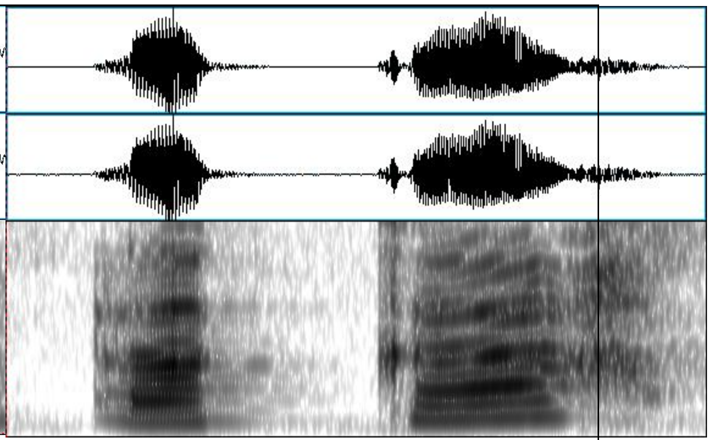
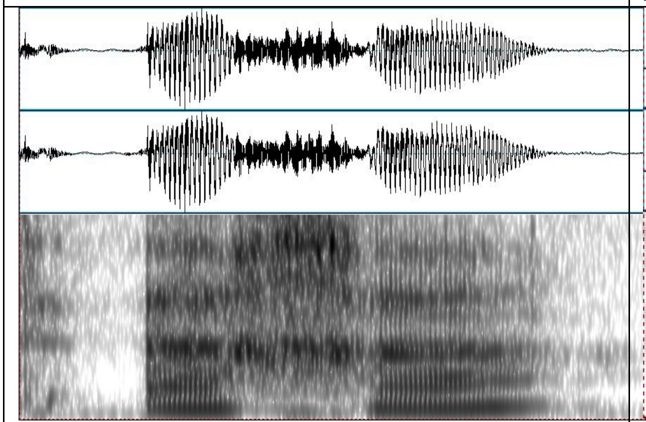
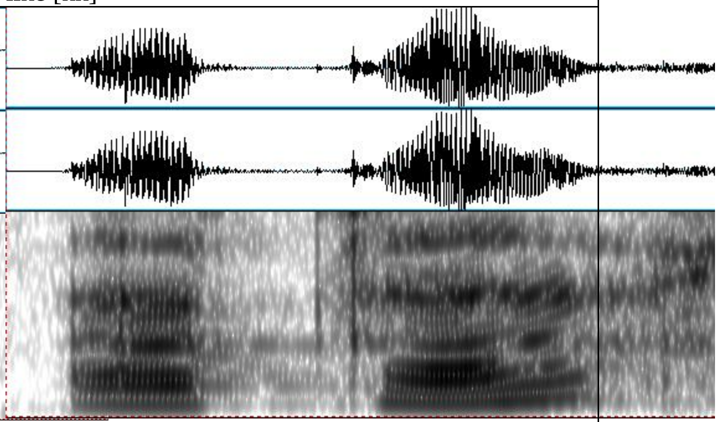
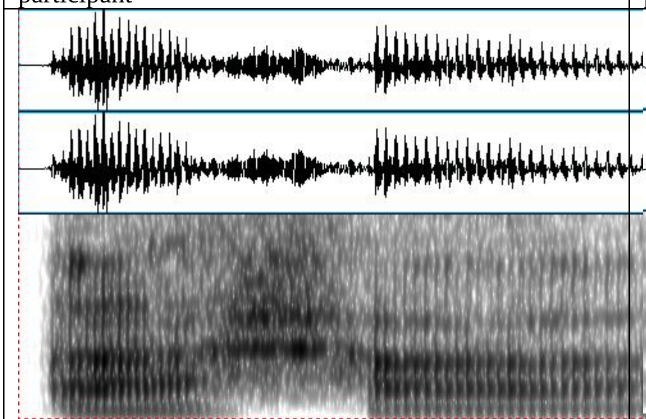
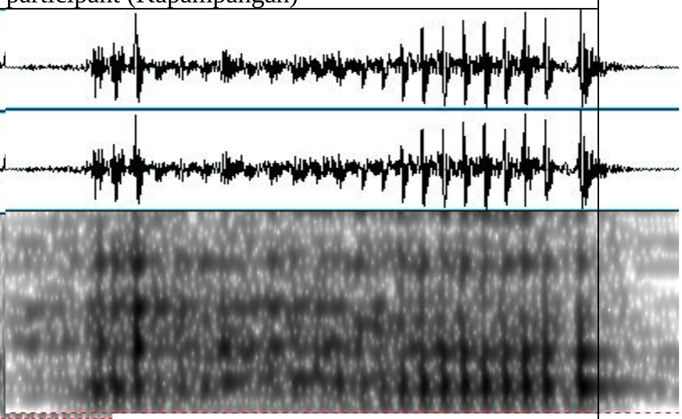
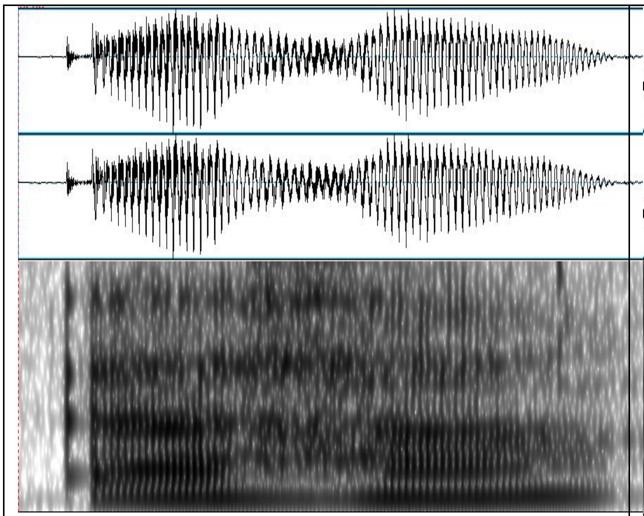
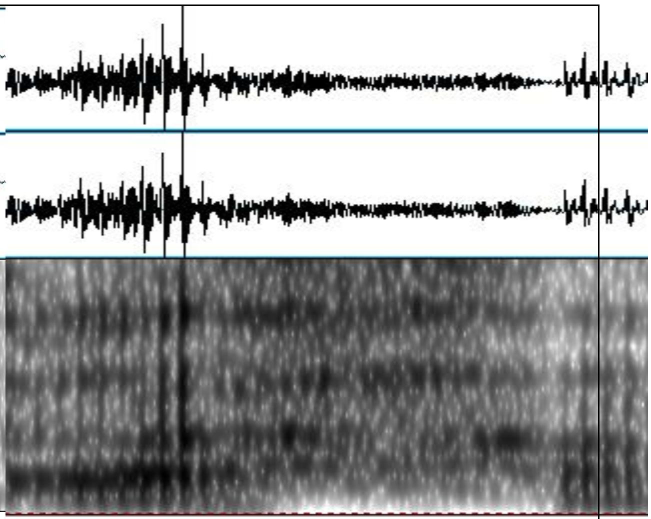
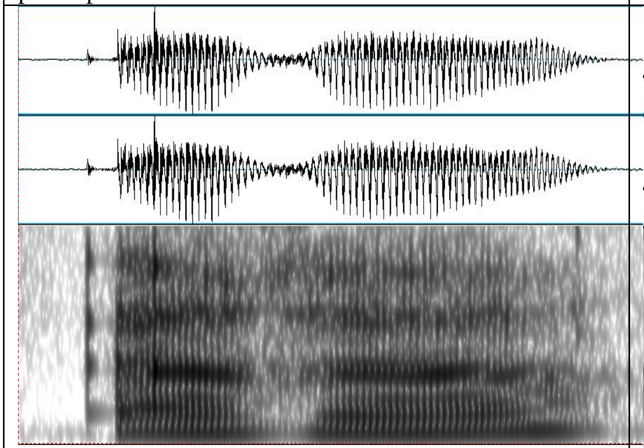
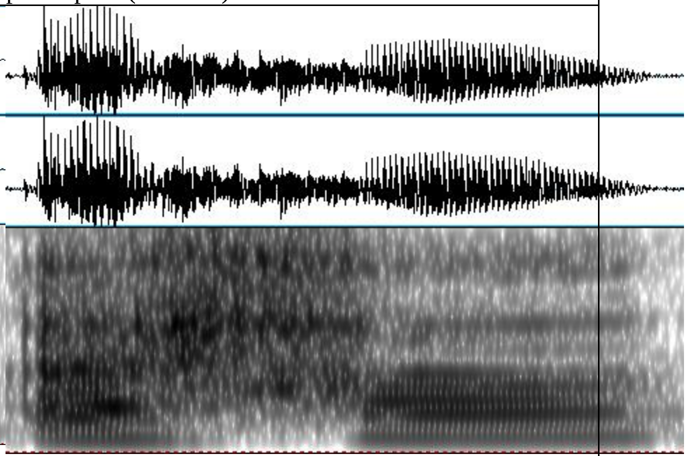
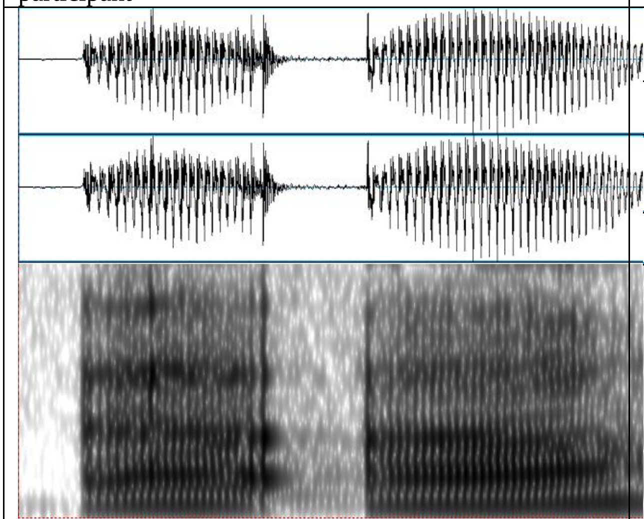
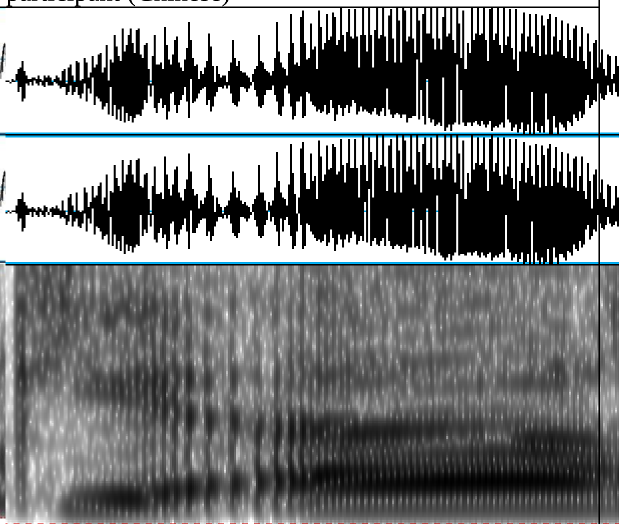
APPENDIX

Name	Age	F/M	Native/Non	Language	Mono-bi-multi-lingual	#Arabic	x	ʕ	ɣ	h	ħ	ʔ
Victoria	21	F	NON	Spanish/German/English	multi	3	√		√	√		√
Marga	22	F	NON	Spanish/English	Bi	½	√		√	√		√
Arbin	22	F	NON	Albany	Mono	2 ½	√			√		
Bairam	23	F	NON	Albany	Mono	3	√			√		√
Maxiaorui	21	F	NON	Chinese/English	Mono	2	√		√	√	√	√
Chahngting	24	F	NON	Chinese	Mono	4	√		√	√	√	√
Ma-ting	22	F	NON	Chinese	Mono	1	√		√	√	√	√
Lara	27	F	NON	Kapampangan/English	Bi	5				√		√
Selena	27	F	NON	Chinese/Spanish/English	multi	5	√		√	√	√	√
Jaymarial	27	F	NON	Kapampangan/English	Bi	3				√		√
Paul	21	M	NON	French/English	Bi	3		√	√			
Dirar	18	M	NON	Indonesian/English	Bi	½	√		√	√	√	√
Abdelhamed	24	M	NON	Kazaxi	Mono	3	√		√	√		√
Abelxan	24	M	NON	Kazaxi	Mono	3 ½	√		√	√		√
Faisal	24	M	NON	Albany	Mono	4				√		
Mohammad	23	M	NON	Chinese/English	Bi	3				√	√	√
Adam	25	M	NON	Chinese/English	Bi	3				√	√	√
Sultan	25	M	NON	Kazaxi	Mono	4	√		√	√		√
Mohammad	23	M	NON	French/Singali/Portuguese	Multi	4 ½		√	√			
Mohammad	22	M	NON	Malaysian/English/Thailand	multi	3	√			√		√
NNSs: Age Average= 23.25 (min=18 max=28)												
Reem	21	F	NATIVE	Arabic/English	Bi	All	√	√	√	√	√	√
Asmaa	21	F	NATIVE	Arabic/English	Bi	All	√	√	√	√	√	√
Heba	21	F	NATIVE	Arabic/English	Bi	All	√	√	√	√	√	√
Duaa	23	F	NATIVE	Arabic		All	√	√	√	√	√	√
Abed	25	M	NATIVE	Arabic		All	√	√	√	√	√	√
Leen	22	F	NATIVE	Arabic/English	Bi	All	√	√	√	√	√	√
Rahaf	22	F	NATIVE	Arabic/English	Bi	All	√	√	√	√	√	√
Marya	21	F	NATIVE	Arabic		All	√	√	√	√	√	√
Loay	23	M	NATIVE	Arabic/English	Bi	All	√	√	√	√	√	√
Mais	23	F	NATIVE	Arabic/English	Bi	All	√	√	√	√	√	√
Mohammad	23	M	NATIVE	Arabic		All	√	√	√	√	√	√
Montasir	24	M	NATIVE	Arabic		All	√	√	√	√	√	√
Yazeed	22	M	NATIVE	Arabic		All	√	√	√	√	√	√
Farah	19	F	NATIVE	Arabic/English	Bi	All	√	√	√	√	√	√
Jehan	21	F	NATIVE	Arabic/English	Bi	All	√	√	√	√	√	√
Jamal	19	M	NATIVE	Arabic/English	Bi	All	√	√	√	√	√	√
Zaid	20	M	NATIVE	Arabic/English	Bi	All	√	√	√	√	√	√
Zaid	22	M	NATIVE	Arabic/English	Bi	All	√	√	√	√	√	√
Ali	21	M	NATIVE	Arabic/English	Bi	All	√	√	√	√	√	√
Mohammad	21	M	NATIVE	Arabic/English	Bi	All	√	√	√	√	√	√

Natives: Age Average= 21.7 (min=19 max=25)

Appendix B: Sample spectrograms

	
The none sense word [aʕa] by an Arabic native female participant	The none sense word [aʕa] by NNS female participant (Kapampangan) (she produced something like [kk]
	
The none sense word [axa] by an Arabic native female participant	The none sense word [axa] by NNS female participant (Kapampangan)
	
The none sense word [aħa] by an Arabic native male participant	The none sense word [aħa] by a male NNS participant (Albany)

	
The none sense word [aha] by an Arabic native female participant	The none sense word [aha] by a male NNS participant (Chinese)
	
The none sense word [aɣa] by an Arabic native female participant	The none sense word [aɣa] by a female NNS participant (Chinese)
	
The none sense word [aʔa] by an Arabic native female participant	The none sense word [aʔa] by a female NNS participant (Chinese)

Average rates and the ranking of each guttural consonant produced by female NNSs

Female Participant / Word	1	2	3	4	5	6	7	8	9	10	Average	Rank
aha	2.5	1.5	1.5	1	3	1	1	1	1	1	1.45	1
aʔa	1	1	1	1	3	3	1.5	2	1	1.5	1.6	2
aħa	1.5	1	1	1.5	3	2	3	2	1	1	1.7	3
axa	1.5	1	3	1.5	3	1.5	2.5	3	1	1	1.9	4
aɣa	3	2.5	1.5	2.5	1.5	1.5	2.5	2	1.5	1.5	2	5
aʕa	2.5	1.5	3	1.5	3	3	2	2	1	1.5	2.1	6

Average rates and the ranking of each guttural consonant produced by male NNSs

Male Participant / Word	1	2	3	4	5	6	7	8	9	10	Average	Rank
aha	1	1	1	1	1	2	1.5	1	1	1	1.15	1
aʔa	1	1	1	1	1	2.5	2	1	1	1	1.25	2
aħa	1.5	1	1	1.5	1	2.5	1	2	2.5	1.5	1.55	3
axa	1	1	1.5	2	1	2	2.5	2	2	1	1.6	4
aɣa	2.5	1	2.5	1	1.5	1	3	2	2.5	2	1.9	5
aʕa	3	1	1	1	2.5	1	3	2.5	3	3	2.1	6

[i] There is no agreement among linguists of whether to include the uvular /q/ or not (cf. Spencer, 2002). Some linguists consider the place feature [guttural] as a non-primary feature for the uvular /q/ and the emphatic consonants (Watson, 2002, p.38; Mashaqba, 2015).

[ii] Emphatics are a group of sounds which are characterized with their articulatory complexity. They involve the coincidence of a primary place feature [coronal] and a secondary coarticulatory feature [pharyngealization] (Mashaqba, et al., 2022).

[iii] Based on fiberscopic experiment, however, laryngeals are excluded; they do not involve pharynx in their articulation because no pharyngeal constriction is involved in their articulation (Zawaydeh, 1999).

[iv] Including (1) guttural consonants lower adjacent vowels, (2) root co-occurence restrictions in Semitic show an avoidance of roots built from two distinct members of the guttural set, (3) laryngeal or pharyngeal may not fall in coda position (for details, see Watson 2002: 37).