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Velar and Uvular Stop Production in Qur'anic Recitation: A Phonetic Study Across Three Speaker Groups

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Abstract
This study examines the acoustic realization of the velar stop /k/ and the uvular stop /q/ in the recitation of Surah Al-'Alaq, with particular attention to the role of articulatory training. Using acoustic analysis, the study investigates spectral and temporal parameters across readers with different levels of tahsin training, focusing on the second formant (F2) and segmental duration as correlates of place-of-articulation contrast. The results indicate that the distinction between /k/ and /q/ is most consistently reflected in spectral properties. The uvular stop /q/ shows systematically lower F2 values than /k/, reflecting posterior tongue dorsum retraction associated with uvular articulation, even within the highly regulated context of

Qur'anic recitation. In contrast, segmental duration does not display a consistent distinction between the two consonants, suggesting that temporal cues are strongly influenced by suprasegmental constraints such as tempo regulation and rhythmic organization. Differences across participant groups further suggest that articulatory training contributes to greater stability in spectral realization. Readers with tahsin training demonstrate more consistent F2 patterns for /q/ than pre-tahsin learners, indicating improved control over articulatory gestures critical for posterior consonant production. Overall, the findings show that spectral cues provide a more reliable basis for distinguishing velar and uvular stops than temporal measures in recitational speech, with important implications for tahsin instruction.

***Keywords**: Qur'anic Recitation; Uvular Stop /q/; Velar Stop /k/; Acoustic Phonetics; Formant Analysis; Articulatory Training*

1. Introduction

The production of consonant sounds in Quranic recitation demands high articulatory accuracy, especially for posterior sounds that involve posterior tongue movements and stable intraoral pressure control. In phonetic studies, posterior consonants such as the velar /k/ and uvular /q/ are considered one of the most complex sound categories for non-native adult learners of Arabic to produce accurately due to their reliance on fine articulatory coordination that is not always present in the learner's first language phonological system (Mashaqba et al., 2022).

Recent Arabic phonetic studies have shown that errors in posterior sounds often manifest as fronting, articulatory undershoot, or instability of closure duration, especially when they occur in low vowel contexts that are sensitive to shifts in the position of the tongue dorsum (Ariyaee & Kochetov, 2021). This phenomenon becomes even more problematic in the context of Qur'anic recitation, because the articulatory difference between /k/ and /q/ is not only phonetic but also has direct

implications for phonological accuracy and prescriptive tajweed norms (Akla & Muyassaroh, 2024).

In the study of Qur'anic learning, tajweed serves as a normative framework that describes the *makhraj* (points of articulation) and properties of letters, including important features such as *isti'lā* and *syiddah* in the uvular sound /q/. However, tajweed is essentially descriptive-normative and does not provide empirical measuring tools to capture variations in sound realization acoustically, especially at the sub-segmental level (Pennington, 2017). Therefore, in recent years, the acoustic phonetic approach has been increasingly seen as relevant to complement tajweed studies with objective, measurement-based data, particularly through formant analysis and segmental duration (Alqadasi et al., 2023).

Previous studies on phonological errors in Quranic recitation have generally focused on identifying error types or sound substitutions based on auditory perception, without systematically linking them to underlying acoustic parameters or articulatory mechanisms (Wulandari, 2020). While these studies make important initial contributions, a purely auditory approach has limitations in revealing subtle phonetic differences, particularly for articulatorily close sounds such as /k/ and /q/ (Johnson, 2012).

Similarly, several recent acoustic studies in the context of Qur'anic recitation have begun to examine aspects of duration, stress, or vowel quality, but generally have not focused their analysis on the velar–uvular contrast or related acoustic findings to the reader's learning stage, such as the differences between pre-tahsin learners and learners who have undergone systematic tahsin training (Khairuddin, 2019). Consequently, there is still limited understanding of how tahsin training contributes to the measurable articulatory stabilization of posterior sounds.

Phonetically, the velar /k/ and uvular /q/ are a highly relevant pair for analysis due to their proximity to each other and their significant acoustic differences. Acoustic phonetic theory establishes that the value of the second formant (F2) serves as the primary indicator of anterior–posterior tongue position, while segmental duration reflects the level of

complexity and articulatory control in the production of dorsal consonants (Ladefoged & Johnson, 2014). Accordingly, deviations in the pronunciation of /k/ and /q/ can be systematically identified through patterns of F2 lowering or raising as well as variations in closure duration, making them particularly suitable objects for data-driven acoustic analysis (Serrurier & Neuschaefer-Rube, 2024).

In the context of tahsin learning for adult learners, several studies report that difficulties in pronouncing the letter /q/ often persist even though learners have a conceptual understanding of tajweed rules, indicating that the problem is articulatory-motor, not solely cognitive (Falya Fadia, 2024). However, empirical evidence comparing the acoustic realization of the sounds /k/ and /q/ between native speakers, pre-tahsin learners, and tahsin learners in a single integrated analytical framework is still very limited, especially in the context of reading certain surahs that are often used in early learning (Meliyani et al., 2024).

Based on this gap, this study is important because it aims to analyze the acoustic phonetic realization of velar /k/ and uvular /q/ in Surah Al-'Alaq by comparing three groups of readers: native Arabic speakers, pre-tahsin adult learners, and tahsin adult learners. By integrating analysis of duration, intensity, and formant values (F1–F3) with articulatory interpretation based on phonetic theory, this study is expected to provide theoretical contributions to the study of Arabic phonetics as well as practical contributions to the development of tahsin learning based on empirical evidence (Maulani & Alwan, 2023).

2. Method

2.1 Research Design and Analytical Framework

This study used a comparative phonetic-acoustic design aimed at comparing the realization of velar /k/ and uvular /q/ in the recitation of the Qur'an by three groups of readers: native Arabic speakers, pre-tahsin adult learners, and tahsin adult learners. This approach was chosen because differences in the place of articulation of dorsal consonants are most accurately represented through continuous acoustic parameters, such as segmental duration and formant values, especially F2, which

directly correlate with the anterior–posterior position of the tongue (Reetz & Jongman, 2020).

The acoustic analysis in this study is quantitative-descriptive, while the interpretation of the results is carried out theoretically by referring to the articulatory model of Arabic phonetics and descriptions of tajweed. Thus, the interpretative component is not applied at the measurement stage, but rather at the explanation stage of the extracted acoustic patterns, thus maintaining the methodological accuracy of experimental phonetic research.

2.2 Participants and Grouping Criteria

The participants of this study were selected using purposive sampling based on controlled phonetic and pedagogical criteria. This technique is commonly employed in phonetic research that emphasizes articulatory comparability across groups rather than large sample sizes (Harrington, 2010). The participants consisted of three groups: native Arabic speakers, pre-Tahsin adult learners, and Tahsin adult learners.

All participants were adult females, had normal hearing, and had no history of speech or neurological disorders. Pre-tahsin and tahsin learners had relatively homogeneous first language backgrounds and comparable levels of exposure to Quranic recitation, with the primary difference being their experience with structured tahsin training. These characteristics were controlled to minimize external variables that could potentially influence the acoustic realization of segmental sounds (Gordon, 2016).

2.3 Speech Material and Data Selection

The speech material for this study was taken from Surah Al-‘Alaq verses 1–5, which were selected based on distributional phonetic considerations. These verses contain several occurrences of the consonants /k/ and /q/ in relatively comparable phonological contexts, especially adjacent to the low vowel /a/, which is known to increase the sensitivity of the analysis to shifts in the position of the tongue dorsum in formant values (Ladefoged & Johnson, 2014).

From the surah, six word segments were selected containing the target consonants /k/ and /q/ in different vowel positions

and environments. This segment selection was intended to allow for comparison across contexts while avoiding generalizations based on a single element, as follows:

Table 1. List of words

Surah/Verses	Sentences Analyzed	Phonetic Transcription	Elevation Phonemes	Phonetic Transcription
Al-'Alaq/1&3	اِقْرَأْ	/iqra/	ق	/q/
Al-'Alaq/1	رَبِّكَ	/rabbika/	ك	/k/
Al-'Alaq/1	خَلَقَ	/xalaq/	ق	/q/
Al-'Alaq/2	خَلَقَ	/xalaqa/	ق	/q/
Al-'Alaq/3	الْأَكْرَمُ	/alakram/	ك	/k/
Al-'Alaq/4	بِالْقَلَمِ	/bilqalam/	ق	/q/

2.4 Data Collection and Recording Procedure

The recordings were conducted in a relatively quiet environment using a digital recording device of phonetic research standard quality. All participants were asked to recite Surah Al-'Alaq verses 1–5 in tartil according to their individual abilities, without tempo or intonation intervention, to maintain the naturalness of the reading.

The recordings were stored in digital format and used for further acoustic analysis. This approach aligns with the common practice of phonetic research, which prioritizes natural sound production as long as the signal quality remains adequate for spectral analysis (Johnson, 2012).

2.5 Acoustic Measurement and Data Extraction

The acoustic analysis was conducted using Praat software version 6.4. Segmentation was performed manually by combining waveform and spectrogram displays to ensure the accuracy of consonant boundary identification, particularly in the closure and release phases of plosives, which are crucial in the analysis of stop consonants (Harrington, 2010).

The acoustic parameters measured included segmental duration, fundamental frequency (F0), intensity, and the first to third formant values (F1–F3). Formant extraction used the Burg algorithm with a maximum formant setting of 5500 Hz for

female participants, a window length of 25 ms, and a time step of 5 ms. Formant values were taken at the midpoint of the vowel after the consonant to capture coarticulation effects that reflect the place of articulation of dorsal consonants (Reetz & Jongman, 2020).

2.6 Analytical Flow and Interpretation Strategy

To maintain methodological coherence, this study was conducted through a sequential and theory-based analytical procedure. The first stage involved grouping participants according to their linguistic background and tahsin experience. The second stage involved selecting relevant speech tokens from Surah Al-'Alaq and recording the recitations. Next, the audio data was manually segmented to isolate the target consonant segments, followed by acoustic parameter extraction using Praat.

In the final stage, the obtained acoustic patterns were compared across groups and phonological contexts. Articulatory interpretation was performed indirectly by linking F2 values and segmental duration patterns to descriptions of velar and uvular consonant articulation in phonetic theory and tajweed. This inferential approach is commonly used in phonetic research when articulatory imaging techniques are not available, as long as the interpretation is based on theoretically established acoustic-articulatory relationships (Reetz & Jongman, 2020).

Figure 1. Research Method Flowchart

3. Results

This section reports the acoustic properties of the velar stop /k/ and the uvular stop /q/ across three speaker groups: native Arabic speakers, pre-tahsin learners, and tahsin learners, based on cross-context measurements of segmental duration and second formant frequency (F2), which are widely recognized as primary acoustic correlates of stop consonant place of articulation (Ladefoged & Johnson, 2014).

Detailed acoustic measurements for each segment, including duration, fundamental frequency (F0), intensity, and formant values (F1–F3), are provided in Appendix A (Tables A1–A6). To facilitate cross-context comparison and reduce redundancy, Table 2 provides a synthesized summary focusing on mean duration and F2 values, as these parameters are most directly associated with articulatory differences between velar and uvular stops (Johnson, 2012).

3.1 Cross-context duration patterns

As shown in Table 2, native speakers produce the uvular stop /q/ with a longer mean duration (621.3 ms ± 160.5) than the velar stop /k/ (520.1 ms ± 261.5). A comparable pattern is observed in the tahsin group, where /q/ exhibits a longer mean duration (525.4 ms ± 93.4) relative to /k/ (402.3 ms ± 258.8).

Table 2. Cross-context acoustic summary of /k/ and /q/ across speaker groups

Consonant	Speaker Group	Mean Duration (ms) ± SD	Mean F2 (Hz) ± SD
/k/	Native	520.1 ± 261.5	1918.5 ± 171.9
/q/	Native	621.3 ± 160.5	1669.5 ± 174.7
/k/	Pre-Tahsin	385.1 ± 134.4	1928.5 ± 317.6
/q/	Pre-Tahsin	427.7 ± 119.1	1673.0 ± 330.9
/k/	Tahsin	402.3 ± 258.8	2017.0 ± 285.3
/q/	Tahsin	525.4 ± 93.4	1645.5 ± 107.9

In contrast, the pre-tahsin group displays a reduced durational distinction between /k/ (385.1 ms ± 134.4) and /q/ (427.7 ms ± 119.1), indicating less consistent temporal differentiation between the two consonants. Across all speaker groups, duration values show substantial variability across phonological contexts, as reflected in the standard deviation measures, suggesting that duration functions as a secondary and less stable acoustic cue for place contrasts (Reetz & Jongman, 2020).

3.2 Cross-context F2 patterns

Consistent differences in F2 values are observed between /k/ and /q/ across all speaker groups. The velar stop /k/

systematically exhibits higher mean F2 values than the uvular stop /q/ in native speakers (1918.5 Hz ± 171.9 vs. 1669.5 Hz ± 174.7), pre-tahsin learners (1928.5 Hz ± 317.6 vs. 1673.0 Hz ± 330.9), and tahsin learners (2017.0 Hz ± 285.3 vs. 1645.5 Hz ± 107.9).

These cross-group patterns indicate a stable spectral distinction between the two consonants, with /k/ associated with higher F2 values and /q/ with lower F2 values across phonological contexts. Notably, the pre-tahsin group demonstrates greater dispersion in F2 values, particularly for /q/, whereas the tahsin group shows comparatively reduced variability, as indicated by smaller standard deviations. Such differences in variability highlight inter-speaker and inter-context fluctuations commonly reported in acoustic studies of non-native Arabic consonant production (Wakhidatul Annisa, 2024).

3.3 Summary of acoustic contrasts

Overall, the results reveal a robust acoustic contrast between /k/ and /q/ across speaker groups, most consistently reflected in F2 differences, while durational contrasts appear more variable across contexts. Fundamental frequency (F0) and intensity values do not exhibit systematic patterns distinguishing /k/ and /q/ across groups and are therefore not discussed further in this section, in line with previous segmental phonetic research emphasizing spectral over prosodic cues for place-of-articulation contrasts (Ladefoged & Johnson, 2014).

4. Discussion

This study examined the acoustic realization of the velar stop /k/ and the uvular stop /q/ in Qur'anic recitation, focusing on how articulatory training influences phonetic outcomes. The findings demonstrate that the contrast between /k/ and /q/ is most consistently reflected in the second formant (F2), whereas temporal parameters such as duration and intensity show greater inter-speaker and inter-group variability (Reetz & Jongman, 2020).

The consistently lower F2 values associated with /q/ provide acoustic evidence for the posterior tongue dorsum retraction that characterizes uvular articulation. According to

established phonetic theory, F2 is closely linked to the front–back dimension of tongue positioning, making it a reliable correlate of dorsal place of articulation (Ladefoged & Johnson, 2014). Within this theoretical framework, uvular stops are expected to systematically lower F2 relative to velar stops, a pattern that has been widely reported in descriptive and analytical accounts of Arabic phonology (Watson, 2007).

The present findings support previous observations that spectral cues, particularly formant frequencies, serve as robust indicators of place-of-articulation contrasts. Compared to temporal cues, spectral parameters are more directly grounded in articulatory configuration and are therefore less susceptible to contextual variation (Gordon, 2016). This robustness is particularly relevant in Qur'anic recitation, a speech genre characterized by controlled tempo, rhythmic regularity, and adherence to recitational norms that may constrain phonetic variability.

Despite these prosodic constraints, the articulatory distinction between /k/ and /q/ remained acoustically detectable in the present data. This suggests that place-of-articulation contrasts are preserved in recitational speech primarily through spectral cues rather than durational ones. Previous phonetic research has similarly shown that durational measures are highly sensitive to speech rate and rhythmic organization, whereas formant-based cues remain relatively stable across speaking styles (Turk et al., 2006).

In contrast to studies that report longer closure or burst durations for uvular stops in spontaneous speech, the present study did not reveal a consistent durational distinction between /k/ and /q/. This discrepancy is plausibly explained by differences in speech context. Segmental duration is well known to be strongly influenced by suprasegmental prosodic structures such as speech rate and rhythmic organization, which shape the temporal unfolding of segments within larger prosodic units (White & Malisz, 2020). In Qur'anic recitation, where tempo regulation and rhythmic balance are strictly maintained, such suprasegmental constraints may suppress segment-specific temporal contrasts that are otherwise observable in less regulated

speech contexts (Gordon, 2016). As a result, duration appears to be a less reliable cue for distinguishing /k/ and /q/ in recitational settings, particularly when compared to spectral parameters that are more directly tied to articulatory configuration (Johnson, 2012).

The effect of articulatory training is most clearly reflected in the performance of tahsin-trained readers, who exhibit more stable and consistently lower F2 values for /q/ compared to pre-tahsin learners. This pattern indicates that structured articulatory instruction enhances control over tongue dorsum positioning, leading to more consistent acoustic realization of uvular consonants. Research on phonetic learning suggests that training tends to strengthen acoustic parameters that are most directly linked to articulatory gestures rather than producing uniform changes across all aspects of speech production (Johnson, 2012).

The present findings also resonate with research on phonological errors in Arabic pronunciation among learners from non-Arabic linguistic backgrounds. Studies have shown that posterior consonants, including uvulars, are particularly prone to misarticulation due to first-language interference and limited articulatory familiarity (Wakhidatul Annisa, 2024). Such difficulties often manifest as substitutions or incomplete articulatory gestures, which may be acoustically reflected in elevated F2 values approaching those of velar consonants.

Similarly, research on phonological errors in the production of hijaiyah consonants among speakers with auditory or articulatory constraints has demonstrated that reduced articulatory control can obscure place-of-articulation contrasts (Allail et al., 2024). Although the populations examined differ from those in the present study, these findings underscore the importance of articulatory precision in maintaining phonetic contrasts, particularly for sounds that rely on posterior tongue positioning.

From a cause–and–effect perspective, the results suggest a coherent chain linking articulatory training to acoustic outcomes. Increased exposure to structured tahsin instruction enhances articulatory awareness and motor control, which in turn facilitates more stable uvular articulation and clearer

acoustic differentiation between /k/ and /q/, most prominently reflected in F2 values. This inferential relationship between acoustic patterns and articulatory mechanisms is well established in phonetic research, especially in contexts where direct articulatory imaging is not available (Reetz & Jongman, 2020).

Theoretically, this study reinforces the view that acoustic analysis provides a valid and informative framework for examining articulatory contrasts in Qur'anic recitation. The findings further demonstrate that not all acoustic parameters contribute equally to the realization of phonological contrasts, highlighting the importance of articulatorily grounded, multi-parameter approaches rather than reliance on single cues such as duration alone (Gordon, 2016). By situating the /k/–/q/ contrast within both phonetic theory and the specific constraints of recitational speech, this study offers a nuanced account of how articulatory precision is maintained in religious reading practices.

5. Conclusion

This study set out to examine how the velar stop /k/ and the uvular stop /q/ are acoustically realized in the recitation of Surah Al-'Alaq, with particular attention to the role of articulatory training. The analysis shows that the distinction between the two consonants is most consistently reflected in spectral properties, especially the second formant (F2), while temporal measures such as segmental duration do not provide a stable basis for contrast in this recitational context.

Across speakers, /q/ is characterized by systematically lower F2 values, a pattern that is compatible with the posterior tongue dorsum retraction required for uvular articulation. This finding indicates that formant-based measures remain sensitive to articulatory configuration even in highly regulated speech genres. By contrast, the lack of a consistent durational difference between /k/ and /q/ suggests that temporal properties are strongly shaped by suprasegmental constraints inherent to Qur'anic recitation, including tempo regulation and rhythmic balance. Under such conditions, duration appears to be a weak and unreliable cue for distinguishing place of articulation.

Differences across participant groups further indicate that articulatory training plays a role in stabilizing acoustic outcomes. Readers with tahsin training produced more consistent F2 patterns for /q/ than pre-tahsin learners, suggesting improved control over posterior tongue positioning. Rather than affecting all acoustic dimensions uniformly, training appears to reinforce those parameters that are most directly tied to the target articulatory gesture. This pattern is consistent with observations from studies of Arabic pronunciation errors, which show that posterior consonants are particularly vulnerable to incomplete or imprecise articulation among learners without sufficient articulatory awareness.

Taken together, these results support the use of acoustic analysis as a practical inferential tool for examining articulatory contrasts in contexts where direct articulatory measurements are not feasible. At the same time, the findings highlight the importance of selecting acoustic parameters that are theoretically motivated. In the case of the /k/–/q/ contrast, spectral cues provide a more reliable window into articulatory behavior than temporal measures, particularly in speech styles governed by strong prosodic constraints.

From a pedagogical perspective, the findings suggest that instruction in Qur'anic recitation may benefit from a greater emphasis on articulatory configuration and awareness of spectral cues, rather than relying predominantly on durational or rhythmic features. Focusing attention on tongue positioning and its acoustic consequences may help learners achieve more stable realizations of uvular consonants and reduce persistent phonological inaccuracies.

Several limitations should be acknowledged. The analysis was confined to a single surah and a limited participant pool, which restricts the extent to which the findings can be generalized to other recitational contexts or learner populations. In addition, the absence of direct articulatory data requires that interpretations be drawn from acoustic evidence alone. Future research could address these limitations by examining a wider range of Qur'anic texts, including more diverse participant

groups, and incorporating articulatory techniques to complement acoustic analysis.

In sum, the present study shows that the /k/–/q/ contrast in Qur'anic recitation is primarily encoded in spectral rather than temporal acoustic cues, and that articulatory training contributes to the stabilization of these cues. By grounding its analysis in phonetic theory while remaining sensitive to the constraints of recitational speech, this study contributes to a clearer understanding of how articulatory precision is maintained and developed in religious reading practices.

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Appendix A. Detailed Acoustic Measurements

Appendix A presents detailed acoustic measurements for each analyzed segment containing the velar stop /k/ and the uvular stop /q/ extracted from Surah Al-'Alaq (verses 1–5). The tables report raw acoustic values, including segmental duration, fundamental frequency (F0), intensity, and formant frequencies (F1–F3), for each speaker group (native speakers, pre-tahsin learners, and tahsin learners).

These detailed tables are provided to ensure data transparency and to allow for fine-grained inspection of individual phonological contexts. In the main Results section, these segment-level data are synthesized into cross-context

summaries focusing on duration and F2 values, which are the primary acoustic correlates of place of articulation in velar and uvular stops.

Table A1. Acoustic data of the segment /iq/ in words /اِقْرَأْ/

No	Recording Source	Segment	Duration (seconds)	Pitch (Hz)	Intensity (dB)	F1 (Hz)	F2 (Hz)	F3 (Hz)
1	Native Speaker	Iq – Iqra-	0.612316	174.9	87.58	~507	~1557	~2730
2	Pre-Tahsin	Iq – Iqra-	0.593536	328.4	80.23	~896	~2110	~3022
3	Tahsin	Iq – Iqra-	0.609028	251.2	85.06	~841	~1753	~2989

Table A2. Acoustic data of the segment /ka/ in words /رَبِّكَ/

No	Recording Source	Segment	Duration (seconds)	Pitch (Hz)	Intensity (dB)	F1 (Hz)	F2 (Hz)	F3 (Hz)
1	Native Speaker	Ka – rabbika-	0.335264	229.8	86.04	~555	~1797	~2968
2	Pre-Tahsin	Ka – rabbika-	0.290098	281.8	84.45	~1021	~2153	~3042
3	Tahsin	Ka – rabbika-	0.219229	208.5	84.24	~1082	~2219	~2924

Table A3. Acoustic data of the segment /laq/ in words /خَلَقَ/

No	Recording Source	Segment	Duration (seconds)	Pitch (Hz)	Intensity (dB)	F1 (Hz)	F2 (Hz)	F3 (Hz)
1	Native	Laq –	0.852625	288.5	84.75	~63	~18	~293

	Speaker	khala q-				8	15	7
2	Pre-Tahsin	Laq – khala q-	0.320611	173.4	87.44	~826	~1750	~2704
3	Tahsin	Laq – khala q-	0.590562	185.7	85.56	~779	~1502	~2722

Table A4. Acoustic data of the segment /qa/ in words /خَلَقَ/

No	Recording Source	Segment	Duration (seconds)	Pitch (Hz)	Intensity (dB)	F1 (Hz)	F2 (Hz)	F3 (Hz)
1	Native Speaker	Qa – khala qa-	0.514186	372.5	85.35	~616	~1836	~3070
2	Pre-Tahsin	Qa – khala qa-	0.424917	207.1	86.83	~709	~1401	~2442
3	Tahsin	Qa – khala qa-	0.407459	234.2	83.06	~790	~1697	~2913

Table A5. Acoustic data of the segment /ak/ in words /الْأَكْرَمُ/

No	Recording Source	Segment	Duration (seconds)	Pitch (Hz)	Intensity (dB)	F1 (Hz)	F2 (Hz)	F3 (Hz)
1	Native Speaker	Ak – Akram-	0.704783	461.2	85.49	~708	~2040	~3096
2	Pre-Tahsin	Ak – Akram-	0.480172	253.0	82.53	~974	~1704	~2747
3	Tahsin	Ak –	0.585371	214.1	84.68	~90	~18	~284

	Akram-		0	15	5

Table A6. Acoustic data of the segment /qa/ in words /بِٱلْقَلَمِ/

No	Recording Source	Segment	Duration (seconds)	Pitch (Hz)	Intensity (dB)	F1 (Hz)	F2 (Hz)	F3 (Hz)
1	Native Speaker	Qa – qalam-	0.506098	261.3	86.63	~778	~1470	~2654
2	Pre-Tahsin	Qa – qalam-	0.371819	180.9	86.42	~736	~1431	~2608
3	Tahsin	Qa – qalam-	0.494699	207	82.89	~740	~1630	~2697