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SPECTROGRAPHIC CHARACTERISTICS OF THE ELEVATION PHONEMES ON THE PRONUNCIATION OF APICO-DENTAL IN SURAH AL-FATIHAH

Siti Marya Ulpah[1]*, Mohamad Zaka Al Farisi[2], Nalahuddin Saleh[3], Zalfa Tsania Rachman[4]
[1,2,3] Universitas Pendidikan Indonesia, Indonesia
[4] Albukhary International University, Malaysia

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***Corresponding Author:**
Name:
Siti Marya Ulpah
Email:
maryaulpah04@upi.edu

Abstract

Correct pronunciation of Qur'anic sounds is crucial, especially for elevation sounds such as /tˤ/ and /dˤ/. This study analyzes their spectrographic characteristics in Surah Al-Fatiha recitation by non-native Arabic speakers, as Indonesian speakers (Ummi teachers in Bandung), compared to native Arabic speakers. Using a qualitative comparative method with a case study approach, data from four participants (two males and two females) were collected through recording, listening, and transcription. The analysis uses Praat to examine parameters such as duration, fundamental frequency (F0), intensity, and formants. The Findings show Indonesian speakers pronounce /tˤ/ with longer duration, higher F0, and lower intensity; for /dˤ/, they show shorter duration, higher F0, and lower intensity than natives. Male Indonesians resemble native speakers more closely. Gender analysis reveals males have shorter durations and lower F0 than females. Both groups show similar formant patterns despite acoustic differences, indicating phonetic adaptation. These findings contribute to Arabic phonetics education by highlighting specific acoustic features in non-native pronunciation.

Keywords: Al-Fatihah; Apico-dental Phonemes; Elevation; Spectrographic.

مستخلص البحث

النطق الصحيح للأصوات القرآن مهم جدًّا، وخصوصا في الأصوات المستعلية مثل /ط/ و /ض/. يهدف هذا البحث إلى تحليل الخصائص الطيفية لهذين الصوتين في تلاوة الفاتحة من قبل غير الناطقين للغة العربية (معلمي أمي في باندونغ) ومقارنتها بنطق الناطقين للغة العربية. وباستخدام الطاريقة النوعية المقارنة مع طريقة دراسة الحالة، تم جمع البيانات من أربعة مشاركين (رجلين وامرأتين) وذلك من خلال التسجيل، والإستماع، والكتابة الصوتية. وتم تحليل البيانات باستخدام برنامج فرات لاستكشاف مدة النطق، والتردد الأساسي، وشدة الصوت، وأنماط الفورمانت. وبينت النتائج أن الناطقين الإندونيسيين ينطقون الصوت /ط/ بمدة أطول، وتردد أساسي أعلى، وشدة صوت أقل؛ وأما الصوت /ض/ فقد لديهم مدة أقصر، وتردد أساسي أعلى، وشدة صوت أقل مقارنة بالناطقين. كما أن الرجال الإندونيسيين أقرب صوتيا إلى الناطقين. وبناء على المقارنة بين الجنسين، فإن الرجال لديهم مدة أقصر وتردد أساسي أقل مقارنة بالنساء. يُظهر كلا المجموعتين أنماط فورمانت متشابهة على الرغم من الإختلافات الصوتية، مما يشير إلى التكيّف الصوتي. تسهم هذه النتائج في تعليم الصوتيات العربية من خلال إبراز الخصائص الصوتية الدقيقة في نطق غير الناطقين.

كلمات أساسية: الفاتحة؛ فونيم طرف اللسان وأصول الأسنان؛ استعلاء؛ الصورة الطيفية.

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Introduction

In Muslim worship, the correct pronunciation of the Quranic letter is crucial for maintaining the clarity of meaning and quality of recitation.[1] Accurate articulation ensures that the recitation aligns with the intended meaning of the verses.[2] This precision helps prevent changes in meaning that could lead to misunderstandings of Qur'anic verses. Since pronunciation is the most fundamental element in verbal communication, special attention must be given to the articulation of Qur'anic sounds to uphold the integrity of the recitation. Correct pronunciation also reflects a Muslim's reverence for the Qur'an in maintaining its authenticity and originality. Thus, precise pronunciation is crucial in maintaining Muslims' worship.

The holy Qur'an is composed using Arabic phonemes, which are part of the Arabic script known as *ḥurūf al-hijā'īyah*.[3] In linguistics, phonemes are defined as the smallest units of sound that can differentiate meaning in a given language. Based on this function, each phoneme has unique characteristics in fulfilling its role. Similarly, the al-hijā'īyah phonemes in the Qur'an have specific pronunciations that must adhere to established rules. These rules are enscapsulated in the science of tajweed, which outlines the principles of places of articulation (*makhārij al-ḥurūf*) and sound characteristics (*ṣifat al-ḥurūf*) to ensure correct pronunciation.[4] Understanding tajweed is essential to maintaining the quality of Qur'anic recitation, ensuring it aligns with how Allah revealed it to the Prophet Muhammad.

Benmamoun & Bassiouney explain that the sound characteristics in tajweed regulate the way of pronouncing the hijaiah phonemes, including the differences in

[1] Yuslina Mohamed, Sulaiman Ismail, and Yoke Suryadama, "Pronunciation of Hijaiyyah's Letter for New Quranic Learners a Contrastive Analysis Study," *Ulum Islamiyyah* 36, no. 01 (April 25, 2024): 73–82, https://doi.org/10.33102/uij.vol36no01.553.

[2] Salmiah Ahmad et al., "The Modeling of the Quranic Alphabets' Correct Pronunciation for Adults and Children Experts," in *2019 2nd International Conference on Computer Applications & Information Security (ICCAIS)* (2019 2nd International Conference on Computer Applications & Information Security (ICCAIS), Riyadh, Saudi Arabia: IEEE, 2019), 1–6, https://doi.org/10.1109/CAIS.2019.8769590; Falya Fadia, Mohamad Zaka Al Farisi, and Hikmah Maulani, "Identifying Pronunciation Errors of the Phoneme Qaf in Al-Qur'an Reading by Non-Native Speakers: A Spectrographic Analysis," *Jurnal Bahasa Dan Sastra* 12, no. 2 (August 21, 2024): 327, https://doi.org/10.24036/jbs.v12i2.129951.

[3] Karin C. Ryding, *Arabic: A Linguistic Introduction* (Cambridge University Press, 2014); Madah Rahmatan et al., "Role And Function Of Phonemes In Phonology For Arabic Communication," *International Journal of Education and Teaching Zone* 2, no. 2 (June 10, 2023): 179–87, https://doi.org/10.57092/ijetz.v2i2.52.

[4] Qo'idul A'dzham, Muh. Nur Rochim Maksum, and Ma'arif, "Analysis of Arabic Phonological Errors in Javanese Speakers," in *Proceedings of the International Conference on Islamic and Muhammadiyah Studies (ICIMS 2023)*, vol. 773, Advances in Social Science, Education and Humanities Research (Paris: Atlantis Press SARL, 2024), 97–109, https://doi.org/10.2991/978-2-38476-102-9_9; Surul Shahbudin Bin Hassan and Muhammad Azhar Bin Zailaini, "Analysis of Tajweed Errors in Quranic Recitation," *Procedia - Social and Behavioral Sciences* 103 (November 2013): 136–45, https://doi.org/10.1016/j.sbspro.2013.10.318.

sound strength known as depression (*istifāl*), and elevation (*isti'lā'*).[5] In phonological terms, elevation refers to a property of sounds pronounced with the elevation of the back of the tongue towards the roof of the mouth, producing an intense sound.[6] The elevation phonemes include /x/, /sˤ/, /dˤ/, /ɣ/, /tˤ/, /q/, and /ðˤ/, which have specific phonetic characteristics and require correct pronunciation techniques. For example, the phonemes /tˤ/ and /dˤ/ are elevation phonemes originating from the same place of articulation, namely apico-dental.[7] Therefore, the incorrect pronunciation of elevation phonemes can impact both sound quality and and semantic clarity.[8]

In practice, many Qur'anic reciters – particularly non-native speaker – still struggle to pronounce the hijaiah phonemes, especially /tˤ/ and /dˤ/, by tajweed rules. For Indonesian speakers, these phonemes do not have equivalents in the Indonesian language, making them particularly difficult to pronounce.[9] AlTalmas et al. recorded recall and precision values for the pronunciation of elevation phonemes at 0.82 and 0.84 respectively, lower than depression phonemes, which reached 0.95 and 0.94.[10] These findings are supported by a Ministry of Religious Affairs survey, which reported that 38.49% of individuals lack Qur'anic literacy skills.[11] Several factors contribute to this issue, including the lack of guidance from tajweed teachers, the limitation of learning time, and differences in native language among non-native speakers. Given that accurate pronunciation of Qur'anic phonemes is fundamental to proper recitation, the correct application of tajweed not only preserves the intended meanings of verses but also ensures the validity and spiritual integrity of Muslim worship. Therefore, addressing pronunciation challenges, particularly in the articulation of elevation phonemes, is critical for improving Qur'anic literacy among non-native speakers.

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[5] Elabbas Benmamoun and Reem Bassiouney, *The Routledge Handbook of Arabic Linguistics* (New York: Routledge, 2018).

[6] John Walker and W Trollope, *A Key to the Classical Pronunciation of Greek, Latin and Scripture Proper Names: In Which the Words Are Accented and Divided Into Syllables* (Fisher, Son, and Jackson, 1840).

[7] Ade Nandang and Abdul Kosim, *Pengantar Linguistik Arab* (Bandung: PT Remaja Rosdakarya Offset, 2023); Ahmad Sayuti Anshari Nasution, *Fonetik dan Fonologi Alquran* (Jakarta: Amzah, 2012).

[8] Hikmah Maulani and Muhammad Dhiya Alwan, "Bilabial Articulation Pronunciation 'B' (L1) and Syafatain Letters 'Ba' (L2): Analysis of the Pronunciation of the Letter Ba in Surah Al-Fatihah," *ALSUNIYAT: Jurnal Penelitian Bahasa, Sastra, Dan Budaya Arab* 6, no. 1 (April 30, 2023): 16–28, https://doi.org/10.17509/alsuniyat.v6i1.54685.

[9] Tatang Tatang and Cucu Hayati, "Sundanese Phonological Interference of the Recitation of Sura Al-Fatiha of the Holy Quran," *Jurnal Pendidikan Bahasa Dan Sastra* 18, no. 2 (February 15, 2019): 235–45, https://doi.org/10.17509/bs_jpbsp.v18i2.15511.

[10] Tareq AlTalmas et al., "Characteristics with Opposite of Quranic Letters Mispronunciation Detection: A Classifier-Based Approach," *Bulletin of Electrical Engineering and Informatics* 11, no. 5 (October 1, 2022): 2817–27, https://doi.org/10.11591/eei.v11i5.3715.

[11] Moh Khoeron, "Survei Kemenag, Indeks Literasi Al-Qur'an Kategori Tinggi," Kementerian Agama Republik Indonesia, accessed May 14, 2025, https://kemenag.go.id/nasional/survei-kemenag-indeks-literasi-al-qur-an-kategori-tinggi-w0A7W.

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Al-Fatihah is one of the surahs with significant importance and a crucial role in the worship practices of Muslims. In addition to being the first surah in the Qur'an, Al-Fatihah holds a strategic function in worship, particularly as an essential pillar of prayer. Rasyid explains that one of the requirements for reciting Al-Fatihah in prayer is *wa murā'atu hurūfīhā*, meaning the preservation of the perfection of its phonemes.[12] If the pronunciation of the phonemes in Al-Fatihah is incorrect, the prayer may be deemed invalid. Therefore, precise articulation, particularly of the elevation phonemes in Al-Fatihah, is essential to preserve the validity of worship and avoid mistakes that could render it invalid.

Previous researchers have conducted several studies on the pronunciation of elevation phonemes. Idris et al., through Graphical User Interface (GUI) analysis, found that 25 phonemes were correctly pronounced, while three phonemes, as /af/, / aɣ/, and /adˁ/, were classified as incorrect. Two of the incorrect phonemes are elevation phonemes.[13] Additionally, Mohamed et al. categorized hijaiah phonemes into three difficulty levels, with /dˁ/ classified as strenuous and /tˁ/ as moderate.[14] Ramli and Rahman identified that only /tˁ/ and /dˁ/ were the most difficult to pronounce among the nine tested phonemes.[15] Alsulaiman et al. explained that non-Arabic speakers often substitute the phoneme /dˁ/ with /ð/, /z/, /d/, and /zˁ/, and the phoneme /tˁ/ with /t/ due to articulation errors that eliminate the emphatic character.[16] Amalya & Hikmah identified phonetic errors in Arabic phonetics by non-native speakers, including the pronunciation of /x/, /dˁ/, and /sˁ/.[17] Pamungkas et al. found that after the post-test, pronunciation errors for the phoneme /tˁ/ reached 10.8%, while for /dˁ/ it was 2.7%.[18] Similarly, Lestari

[12] Amjad Rasyid, *Syarah Safinatun Naja: Ringkasan Akidah, Sirah Nabawiah, Ibadah dalam Madzhab Asy-Syafi'i* (Jakarta: Pustaka Al-Kautsar, 2021).

[13] Sulbalqiah Idris et al., "The Classification of Actual Pronunciation of Quranic Alphabets for Non-Arab Speaker," *PERINTIS eJournal* 11, no. 1 (September 12, 2021), https://perintis.org.my/ejournalperintis/index.php/PeJ/article/view/109.

[14] Yuslina Mohamed et al., "A Systematic Review Of Arabic Phonetic: Hijaiyyah's Pronunciation Among New Learners," *Ijaz Arabi Journal of Arabic Learning* 7, no. 2 (June 24, 2024), https://doi.org/10.18860/ijazarabi.v7i2.24173.

[15] Issraq Bin Ramli and Mohd Zaki Abd Rahman, "Aplikasi Teori Mahjub Terhadap Pembaikan Sebutan Bunyi Bahasa Arab Dalam Kalangan Pelajar Sabah - Application of Mahjub Theory in Arabic Pronunciation among Sabahan Students," *MANU Jurnal Pusat Penataran Ilmu Dan Bahasa* 25 (August 23, 2017), https://jurcon.ums.edu.my/ojums/index.php/MANU/article/view/765.

[16] Mansour Alsulaiman et al., "Pronunciation Errors of Non-Arab Learners of Arabic Language" (2014 International Conference on Computer, Communications, and Control Technology (I4CT), Langkawi, Malaysia: IEEE, 2014), 277–82, https://doi.org/10.1109/I4CT.2014.6914189.

[17] Dewi Ayu Amalya and Khizanatul Hikmah, "Error Analysis of Errors in Arabic Phonetics at the University," *Indonesian Journal of Islamic Studies* 11 (February 27, 2023), https://doi.org/10.21070/ijis.v11i0.1643.

[18] Muhammad Ibnu Pamungkas et al., "Error Analysis of Consonant Pronunciation in Arabic Language among Fifth-Grade Students," *Ta'lim al-'Arabiyyah: Jurnal Pendidikan Bahasa Arab & Kebahasaaraban* 8, no. 1 (June 30, 2024): 56–71, https://doi.org/10.15575/jpba.v8i1.34596.

identified one of the pronunciation errors in Al-Fatihah as pronouncing /tˤ/ as /t/ in the word /sˤira:tˤa/.[19]

From the above explanation, it is evident that the pronunciation difficulties involving the phonemes /tˤ/ and /dˤ/ is more dominant than other elevation phonemes. Interestingly, these two phonemes share the same point of articulation as apico-dental consonants.[20] However, research specifically examining their spectral and spectrographic characteristics in Al-Fatihah recitation remains limited. Most previous studies have focused on students and relied on subjective assessments rather than technological tools. This gap highlights the need for phonetic technology to study these phonemes' pronunciation more scientifically. Therefore, this study aims to observe the spectrographic characteristics of elevation phonemes, specifically /tˤ/ and /dˤ/, in Al-Fatihah, as pronounced by Ummi teachers. For example, Thohir & Dzakiruddin highlight that teachers must carefully observe and correct mistakes in differentiating /dˤ/ from /d/.[21] Ideally, correct pronunciation can be achieved with guidance from teachers who understand tajweed.[22]

Along with the development of technology, acoustic analysis has emerged a valuable tool to support tajweed learning, particularly in analyzing the pronunciation of the phonemes of the holy Qur'an. One of the most effective tools for this analysis is Praat, a widely used software for phonetic analysis.[23] Praat has the potential to provide a more scientific and objective pronunciation guide, offering a solution to pronunciation difficulties.[24] This software enables spectral analysis of sounds produced during recitation, including frequency, intensity, duration, and formants, which are essential in determining the quality of elevated pronunciation.[25]

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[19] Yuni Lestari, "Analisis Kesalahan Fonologi Dialek Etnis Lampung Dalam Membaca Q.S Al-Fatihah Dan Al-Zalzalah," *Lahjah Arabiyah: Jurnal Bahasa Arab Dan Pendidikan Bahasa Arab* 3, no. 1 (January 30, 2022): 62–70, https://doi.org/10.35316/lahjah.v3i1.62-70.

[20] Sahkholid Nasution et al., "A Contrastive Analysis of Indonesian and Arabic Phonetics," *KnE Social Sciences*, August 1, 2019, https://doi.org/10.18502/kss.v3i19.4899.

[21] Muhammad Thohir and Muhammad Dzakiruddin, "Popular Phonetic Mapping in The Qur'an and Its Implications on Teaching Arabic for Non-Native Speakers," *Jurnal Al Bayan: Jurnal Jurusan Pendidikan Bahasa Arab* 14, no. 1 (March 6, 2022): 20–39, https://doi.org/10.24042/albayan.v14i1.9757.

[22] Akla Akla and Muyassaroh Muyassaroh, "Arabic Phonetics and Phonemics Instruction in Islamic Boarding School for Children," *An Nabighoh* 26, no. 2 (December 28, 2024): 303–14, https://doi.org/10.32332/an-nabighoh.v26i2.303-314.

[23] Nurzayyini Nafisah, Sofyan Sauri, and Yayan Nurbayan, "Al-Akhṭā'u al-Ṣautiyah Fī Qirā'ati al-Nuṣūsi al-'Arabiyyah Bi Istikhdāmi Taṭbīqāti Praat," *ALSUNIYAT: Jurnal Penelitian Bahasa, Sastra, Dan Budaya Arab* 5, no. 1 (April 26, 2022): 30–45, https://doi.org/10.17509/alsuniyat.v5i1.41710.

[24] Štefan Beňuš, *Investigating Spoken English: A Practical Guide to Phonetics and Phonology Using Praat* (Cham: Springer International Publishing, 2021), https://doi.org/10.1007/978-3-030-54349-5.

[25] "Praat: Doing Phonetics by Computer," www.praat.org, accessed May 15, 2025, https://www.fon.hum.uva.nl/praat/.

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The originality of this research lies in its detailed phonetic analysis of the elevation phonemes /tˤ/ and /dˤ/ in Al-Fatihah, as recited by Ummi teachers. Its distinctiveness also stems from its approach, which analyses pronunciation based on phonetic properties using the Praat software. This provides an objective representation of the participants' correct pronunciation. Unlike previous studies that broadly address pronunciation issues, this research focuses on the precise acoustic features of Arabic phonemes. Therefore, this research's results are expected to improve the Qur'an teacher's understanding of *al-hijā'īyah* pronunciation, particularly concerning the elevation characteristics.

Method

This research used a comparative qualitative method, aligning with the researcher's interpretive research paradigm. The study explores and describes the pronunciation characteristics of the phonemes /tˤ/ and /dˤ/ among non-native speakers, specifically Indonesians. The researcher conducted observations and comparisons with the interpretation of the data found, then describes the findings of the comparison results. A case study approach was adopted, as the participants—Ummi teachers from the Sundanese ethnic group—represent a specific, contextually relevant group for in-depth examination.

The sampling was conducted using a non-probability sampling technique with a purposive sampling method. The sample was selected based on specific criteria relevant to the research's purpose and needs.[26] The study involved four non-native speakers (NNS), two males and two females, aged 30–40. The selection of this sample aims to explore the acoustic differences caused by variations in language background and gender. All participants were certified Ummi teachers (the method of Quranic learning) in Bandung, chosen based on their ability to recite the Qur'an following tajweed rules. Additionally, the study included a recorded recitation of male and female native speakers (NS), which will serve as a comparison with NNS.

Table 1. Description of The Acronym Research Sample

Acronym	Description	Research Sample
NS-M	Native Speaker Male	
NS-F	Native Speaker Female	
NNS	Non-Native Speaker	
PM-1	Participant Male 1	Non-Native Speakers
PM-2	Participant Male 2	
PF-1	Participant Female 1	
PF-2	Participant Female 2	

[26] Manish Gupta, Musarrat Shaheen, and K. Prathap Reddy, eds., *Qualitative Techniques for Workplace Data Analysis:*, Advances in Business Information Systems and Analytics (IGI Global, 2019), https://doi.org/10.4018/978-1-5225-5366-3.

This research involved the elevation of phonemes in Al-Fatihah, specifically those that share the same point of articulation, apico-dental consonants. These consonants are produced when the tongue tip works with the upper teeth to block the air from the lungs.[27] The apico-dental consonants with the characteristic of elevation are the phonemes /tˤ/ and /dˤ/. Case the following details:

Table 2. List of Words

Surah/Verses	Sentences Analyzed	Phonetic Transcription	Elevation Phonemes	Phonetic Transcription
Al-Fatihah/6 & 7	صِرَاطَ	/sˤira:tˤa/	ط	/tˤ/
Al-Fatihah/7	الْمَغْضُوْبِ	/almaɣdˤu:bi/	ض	/dˤ/
Al-Fatihah/7	الضَّآلِّيْنَ	/adˤdˤa:lli:n/	ض	/dˤ/

The data were collected through recording, listening, and transcription. The pronunciation of phonemes /tˤ/ and /dˤ/ by the participants was recorded using high-quality audio devices in MP3 format to ensure sound accuracy. Next, the researcher carefully listened to the recordings to identify pronunciation patterns. Following this, the pronunciation sounds were transcribed into visual form using Praat version 6.4.21 to make it easier to analyze the acoustics.

Data were analyzed using Praat Voice Analysis. The software allows the identification of acoustic characteristics from the recording participants' voices. The researcher examined the frequency fundamental (F0), duration, and intensity of sounds and the differences in vowel and consonant sounds. The analysis results from NNS are compared with NS to identify differences in the acoustic pattern of pronunciation of the phonemes /tˤ/ and /dˤ/ in Al-Fatihah. This comparative analysis provided insight into the phonetic adaptations and challenges experienced by non-native speakers.

Result and Discussion

One of the most distinctive features of sound Arabic phonetics is that specific phonemes are pronounced strongly, while others are more softly articulated.[28] Among the more forceful are the phonemes /tˤ/ and /dˤ/ which are pronounced with a high pitch, thickness, and strength. In pronunciation, this strength is marked by the strength of the produced sound, the length of the sound, and the sound pressure. These indicators are represented by acoustic elements such as duration,

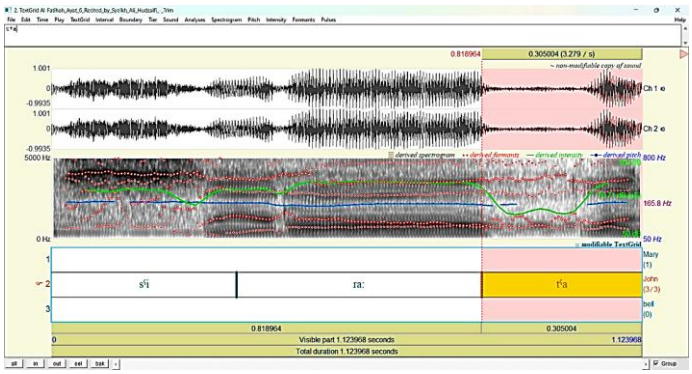
[27] L. F. Brosnahan and Bertil Malmberg, *Introduction to Phonetics* (CUP Archive, 1975); Marwa Adel Nasser, "Error Analysis of the Pronunciation of Arabic Consonants by Egyptian Learners," *CDELT Occasional Papers in the Development of English Education* 75, no. 1 (July 1, 2021): 121–52, https://doi.org/10.21608/opde.2021.208431.

[28] Daniel Jones, *The Pronunciation of English* (Cambridge University Press, 1966).

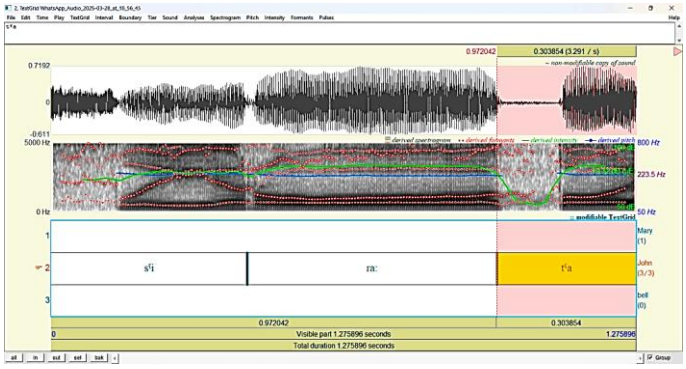
frequency, and intensity.[29] The strength and length of these sounds align with the concept of word stress, which also involves F0, duration, and intensity.[30] In spectrographic analysis, identifying the formant is necessary to determine the point of articulation. Formant frequencies are generated within the vocal tract.[31] Generally, human speech contains three primary formant characteristics, F1, F2, and F3.[32]

Spectrographic Analysis of the Phonemes /tˤ/ and /dˤ/ by Native Speakers

The following spectrogram illustrates the phonetic analysis of NS pronouncing phonemes /tˤ/ and /dˤ/ in the word /sˤiraːtˤa/ and /adˤdˤaːlliːn/.



Spectrogram 1. Visualization of the Pronunciation of /tˤ/ in the Word /sˤiraːtˤa/ by NS-M



Spectrogram 2. Visualization of the Pronunciation of /tˤ/ in the Word /sˤiraːtˤa/ by NS-F

Spectrograms 1 and 2 illustrate NS-M's and NS-F's pronunciation of /tˤ/ in /sˤiraːtˤa/. The waveform reflects the characteristics of an apico-dental consonant,

[29] Peter Roach, *English Phonetics and Phonology: A Practical Course* (Cambridge University Press, 2009).

[30] Salji, Al Farisi, and Saleh, "Word Stress in Santri Utterance: A Comparative Analysis of Acoustic Phonetics," *International Journal of Arabic Language Teaching* 6, no. 02 (August 14, 2024): 167–81, https://doi.org/10.32332/ijalt.v6i02.9647.

[31] D. B. Fry, *Acoustic Phonetics: A Course of Basic Readings* (Cambridge University Press, 2009).

[32] Yaser S. Natour et al., "Formant Frequency Characteristics in Normal Arabic-Speaking Jordanians," *Journal of Voice* 25, no. 2 (March 2011): e75–84, https://doi.org/10.1016/j.jvoice.2010.10.018.

characterized by the contact of the tongue tip with the upper teeth, effectively blocking airflow. During articulation, the root of the tongue elevates and retracts, creating a complete closure (stop/emphatic), followed by a sudden burst of air.[33] Emphatic character is indicated by more significant tongue root retraction.[34] The spectrographic characteristics of the /tˤ/ are marked by a silent gap, a defining feature of plosive consonants.[35]

Plosive consonants generally have a shorter duration, with the silent gap and burst release lasting about 0.150 s, aligning with Al-Ani, who stated that the silent gap typically lasts between 80-100 ms, followed by a burst lasting around 30–40 ms.[36] As noted in Jamil's research, the F0 observed in Spectrogram 1 is 165.8 Hz, which falls within the typical male voice frequency range of 60–240 Hz.[37] In contrast, Spectrogram 2 shows an F0 of 223.5 Hz, within the typical female voice frequency range of 180–400 Hz. During the silent gap, the energy level is minimal. Upon release, the F0 rises without fricative noise, confirming that /tˤ/ is voiceless.[38] In terms of intensity, the /tˤ/ exhibits low intensity during the silent gap, 76.71 dB by NS-M and 79.32 dB by NS-F, due to the absence of energy, followed by an increase upon release, ensuring a clear emphatic pronunciation.

In summary, NS-M's and NS-F's pronunciation of /tˤ/ is marked by a short duration, silent gap, and burst release, leading to a temporary F0 decrease. As a voiceless consonant, its F0 is undetectable, and its intensity highlights vocal strength. The spectrographic features exhibited by NS-M and NS-F align with the general definition of /tˤ/ as an apico-dental, plosive, voiceless, and emphatic consonant.[39]

[33] Moch. Syarif Hidayatullah, *Cakrawala Linguistik Arab* (Jakarta: Penerbit PT Grasindo, 2017).

[34] Abdullah H. Alfaifi, Malgorzata E. Cavar, and Steven M. Lulich, "Tongue Root Position in Hijazi Arabic Voiceless Emphatic and Non-Emphatic Coronal Consonants" (179th Meeting of the Acoustical Society of America, Acoustics Virtually Everywhere, 2020), 060004, https://doi.org/10.1121/2.0001391.

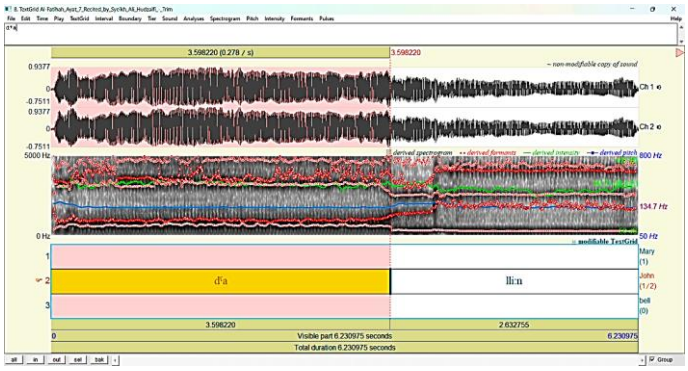
[35] Jeri Sukmawijaya, Sutiono Mahdi, and Susi Yuliawati, "An Acoustic Analysis of Voiceless Alveolar Plosive /t/ in Sundanese, Indonesian, and English by Sundanese Speakers," *Metahumaniora* 10, no. 1 (April 30, 2020): 1, https://doi.org/10.24198/mh.v10i1.26597.

[36] Salman H Al-Ani, *Arabic Phonology: An Acoustical and Physiological Investigation* (Mouton & Co, 2014).

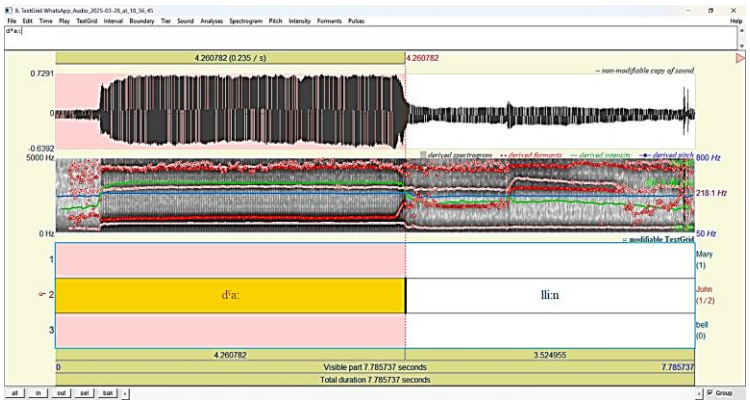
[37] Khairul Jamil, "Struktur Frekuensi Dalam Bahasa Arab Pada Modus Kalimat Deklaratif, Interogatif, Dan Imperatif Oleh Pembelajar Bahasa Arab Kota Medan," *Ihya Al-Arabiyah: Jurnal Pendidikan Bahasa Dan Sastra Arab* 3, no. 2 (July 18, 2017), https://jurnal.uinsu.ac.id/index.php/ihya/article/view/827.

[38] Afrinta Puspandari, "Erroneous Production of Apico-Dental Fricative Consonant Sounds by Javenese School Students," *Lexicon* 2, no. 2 (December 28, 2018), https://doi.org/10.22146/lexicon.v2i2.42179.

[39] Tej Bhatia, *Punjabi* (Routledge, 2013).



Spectrogram 3. Visualization of the Pronunciation of /dˤ/ in the Word /adˤdˤa:lli:n/ by NS-M



Spectrogram 4. Visualization of the Pronunciation of /dˤ/ in the Word /adˤdˤa:lli:n/ by NS-F

Spectrograms 3 and 4 show NS-M's and NS-F's pronunciation of /dˤ/ in the word /adˤdˤa:lli:n/. The waveform indicates that /dˤ/ is a plosive consonant, producing a transient sound.[40] Additionally, the waveform exhibits strong vocal vibration, indicating voicing and high intensity resulting from increased articulatory pressure. Energy concentration in the low-to-mid frequency range is a distinctive feature of emphatic consonants like phoneme /dˤ/.

In Spectrogram 3, dˤ/ extends for approximately 3.598 s, indicating that the vowel is pronounced as long (mad). Meanwhile, Spectrogram 4 shows an extended dˤ/ duration of 4.260 s, significantly longer than in Spectrogram 3. However, as a transient sound, the duration of /dˤ/ is typically very short, making its regularity difficult to identify.[41] Additionally, it is affected by the istithālah characteristic, where the pronunciation of this phoneme extends along one edge of the tongue root towards the front. Based on Spectrograms 3 and 4, the F0 values are 134.7 Hz and 218.1 Hz, aligning with the typical F0 range for males and females.[42] Intensity

[40] Fitria Lathifah, Syihabuddin Syihabuddin, and M. Zaka Al Farisi, "Analisis Kesalahan Fonologis Dalam Keterampilan Membaca Teks Bahasa Arab," *Arabiyat : Jurnal Pendidikan Bahasa Arab Dan Kebahasaaraban* 4, no. 2 (December 28, 2017), https://doi.org/10.15408/a.v4i2.6273.

[41] Yusuf Irawan, *Fonetik Akustik* (CV Angkasa, 2017).

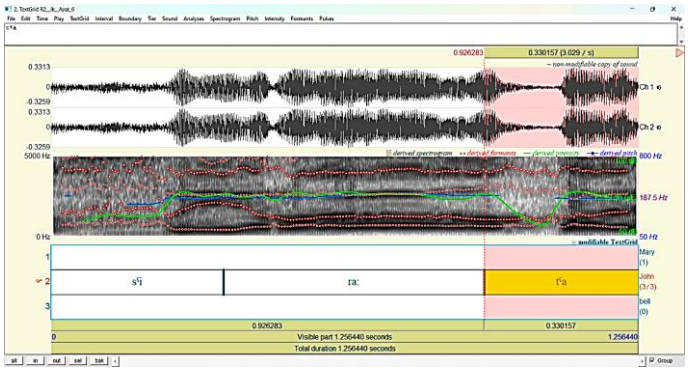
[42] Alan Cruttenden, *Intonation* (Cambridge University Press, 1997).

levels further confirm this pattern, with 82.51 dB in Spectrogram 3 and 83.17 dB in Spectrogram 4, suggesting strong articulation and clarity of the emphatic phoneme /dˤ/.

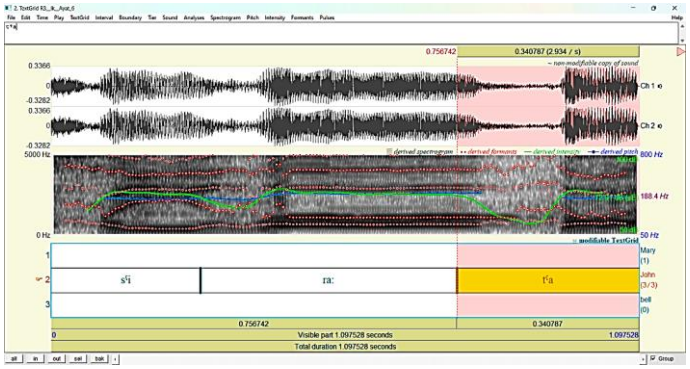
In conclusion, NS-M's and NS-F's pronunciation of /dˤ/ exhibits the characteristics of elevation phonemes. This is demonstrated by its long duration, representing the istithālah characteristic, maximum vocal height, and high-intensity values, which reflect a strong and thick sound quality. The spectrographic features exhibited by NS align with the general definition as an apico-dental, plosive, voiced, and emphatic.[43]

Spectrographic Analysis of The /tˤ/ Phoneme by Non-Native Speakers

The following shows spectrogram as an illustration of the phonetic review of NNS pronouncing phonemes /tˤ/ in the word /sˤiraːtˤa/ verses 6 and 7.



Spectrogram 5. Visualization of the Pronunciation of /tˤ/ in the Word /sˤiraːtˤa/ verse 6 by PM-1

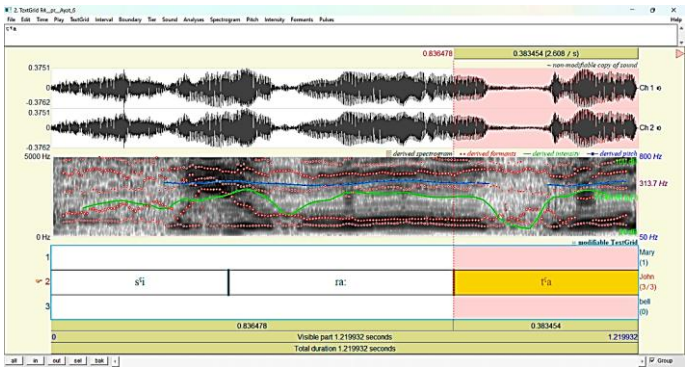


Spectrogram 6. Visualization of the Pronunciation of /tˤ/ in the Word /sˤiraːtˤa/ verse 6 by PM-2

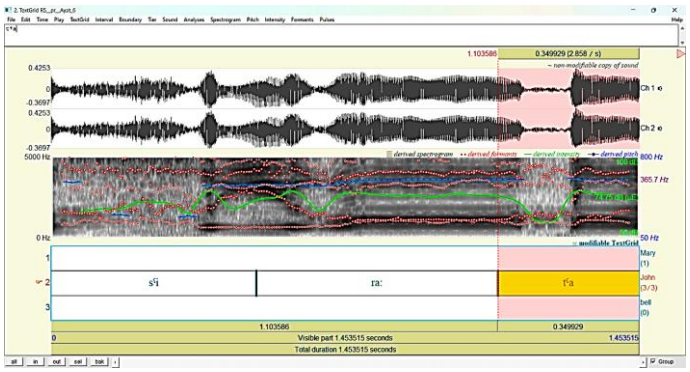
Spectrograms 5 and 6 show the acoustic analysis results for the pronunciation of /tˤ/ in verse 6 by PM-1 and PM-2. The pronunciation duration was 0.330 s for PM-1 and 0.340 s for PM-2, reflecting a variation influenced by differences in vocal stress. The F0 values for the male non-native speakers, PM-1

[43] Basem I. M. Al-Raba'a, "The Manner of Articulation of the Emphatic /d?/ In Both Saudi and Palestinian Dialects," *International Journal of Language and Linguistics* 3, no. 1 (2015): 1, https://doi.org/10.11648/j.ijll.20150301.11.

and PM-2, were recorded at 187.5 Hz and 188.4 Hz, respectively. These values fall within the typical adult male frequency range of 60–240 Hz, indicating normal vocal fold vibration during the pronunciation of the /tˤ/ phoneme. Notably, PM-2 exhibited a slightly higher pitch, which resulted in a clearer transition between the /tˤ/ consonant and the following /a/ vowel, suggesting greater phonetic clarity in the release phase. In terms of intensity, PM-1 produced a sound with an intensity of 73.99 dB, higher than PM-2's 72.91 dB. This suggests that PM-1 had a more explosive burst release after the /tˤ/, making the burst more distinct. In contrast, PM-2 used a more controlled vocal force, resulting in a smoother transition from /tˤ/ to /a/ vowel.



Spectrogram 7. Visualization of the Pronunciation of /tˤ/ in the Word /sˤira:tˤa/ verse 6 by PF-1



Spectrogram 8. Visualization of the Pronunciation of /tˤ/ in the Word /sˤira:tˤa/ verse 6 by PF-2

Spectrograms 7 and 8 show the results of the acoustic analysis of the /tˤ/ pronunciation by PF-1 and PF-2. PF-1 used a relatively longer duration of 0.383 s compared to PF-2, which took 0.349 s to pronounce the /tˤa/ segment. The longer pronunciation duration of the vowel /a/ by PF-1 is due to greater emphasis applied during articulation. The F0 values for PF-1 and PF-2 fall within the ideal frequency range for female speakers, as 180–400 Hz. The recorded F0 values are 313.7 Hz for PF-1 and 365.7 Hz for PF-2. This difference indicates that PF-2's vocal cords vibrated more rapidly, caused by laryngeal elevation and increased vocal cord tension during the pronunciation of /tˤ/. Conversely, PF-1's lower F0 value

resulted from a lower laryngeal position, leading to slower vocal cord vibration. The intensity levels produced by PF-1 and PF-2 were nearly identical at 74.48 dB and 74.75 dB, respectively. This suggests intense airflow pressure during pronunciation and emphasis in the articulation of the /tˤ/.

Table 3. Acoustic Data of /tˤ/ Pronunciation in The Word /sˤira:tˤa/ verse 6

Participant	Duration (s)	Pitch (Hz)	Intensity (dB)	F1	F2	F3
NS-M	0.305	165.8	76.71	687.2	1111.0	2896.8
NS-F	0.303	223.5	79.32	684.0	1262.9	3056.3
PM-1	0.330	187.5	73.99	689.0	1227.3	2788.7
PM-2	0.340	188.4	72.91	744.5	1285.6	2817.7
PF-1	0.383	313.7	74.48	751.9	1307.5	2963.1
PF-2	0.349	365.7	74.75	944.4	1376.7	3305.0

Table 3 presents acoustic data of the phoneme /tˤ/ in the word /sˤira:tˤa/. The analysis reveals that NS-M and NS-F produce shorter duration, lower F0, and higher intensity than NNS. While NNS duration is close to NS, it is slightly longer due to extended vowel emphasis and burst release of /tˤ/. According to Al-Ani, plosive consonants typically have short durations, with an 80–100 ms silent gap followed by a 30–40 ms burst. Among NNS, males articulate /tˤ/ more briefly than females, consistent with Ningrum et al's findings.[44]

The F0 of NS-M and NS-F is lower than that of NNS, contrasting to Mutmainnah et al., who found NS had higher frequency values than NNS.[45] This difference may stem from NNS producing sharper articulation. In terms of gender comparison, NNS males have a lower frequency than NNS females when pronouncing /tˤ/, aligning with Jamil's findings that males typically range from 60–240 Hz and females from 180–400 Hz. Thus, these findings suggest that male voices generally have lower frequencies than female voices.

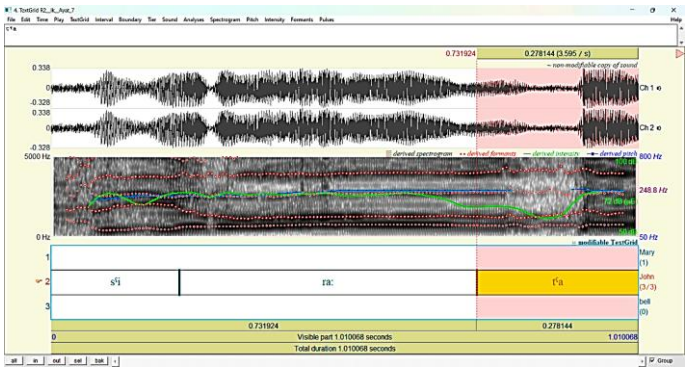
Furthermore, NS-M and NS-F show higher intensity values compared to NNS, indicating their ability to more effectively emphasize the emphatic features of the /tˤ/ phoneme. These results are consistent with Mutmainnah et al., who found that native speakers tend to produce speech with greater intensity. Interestingly, within the NNS group, male participants show lower intensity than female

[44] Dwi Kurnia Surya Ningrum, Siti Suriyani, and Tengku Syarfina, "Analisis Frekuensi, Durasi, Dan Intensitas Suara Laki-Laki Dan Perempuan Bahasa Banjar Menggunakan Perangkat Lunak Praat," *AKSARA: Jurnal Bahasa Dan Sastra* 25, no. 1 (April 4, 2024), https://doi.org/10.23960/aksara/v25i1.pp185-200.

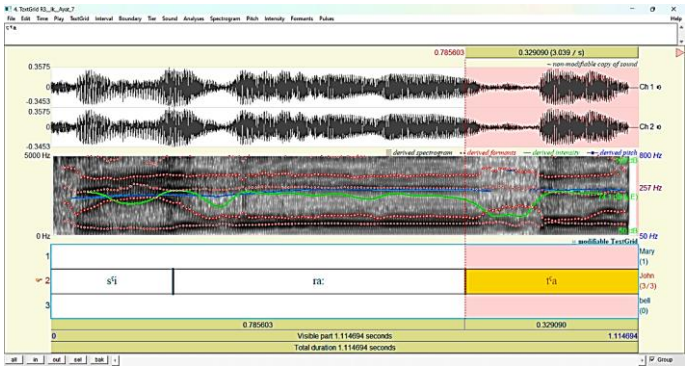
[45] Salma Mutmainnah et al., "The Prosody of Arabic Interrogative Speech (An Acoustic Phonetic Study)," *IDEAS: Journal on English Language Teaching and Learning, Linguistics and Literature* 12, no. 2 (January 8, 2025), https://doi.org/10.24256/ideas.v12i2.6071.

participants—a pattern that differs from Pranoto's findings, which reported the opposite.[46]

The articulation process and tongue position in pronouncing the /tˤ/ can be identified through both NS and NNS F1, F2, and F3 values. The formant values in NS align with Altalmas et al's findings, while NNS shows similar values, indicating a close approximation to NS pronunciation.[47] Additionally, NNS males have lower F1, F2, and F3 values than NNS females. This characteristic aligns with Arabic phonetic principles, where emphatic consonants lower formant frequencies and enhance the intensity of the following vowel.[48]



Spectrogram 9. Visualization of the Pronunciation of /tˤ/ in the Word /sˤira:tˤa/ verse 7 by PM-1



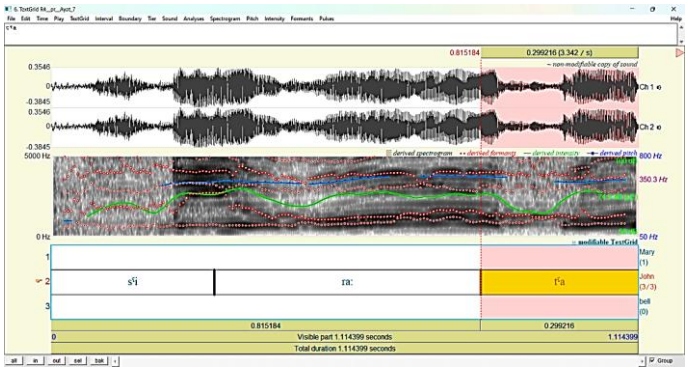
Spectrogram 10. Visualization of the Pronunciation of /tˤ/ in the Word /sˤira:tˤa/ verse 7 by PM-2

[46] M. Sholihin Pranoto, "Analisis Frekuensi, Durasi Dan Intensitas Suara Laki-Laki Dan Perempuan Jawa Menggunakan Perangkat Lunak Praat," *Lingua: Jurnal Bahasa Dan Sastra* 14, no. 2 (2018), https://journal.unnes.ac.id/nju/lingua/article/view/15237.

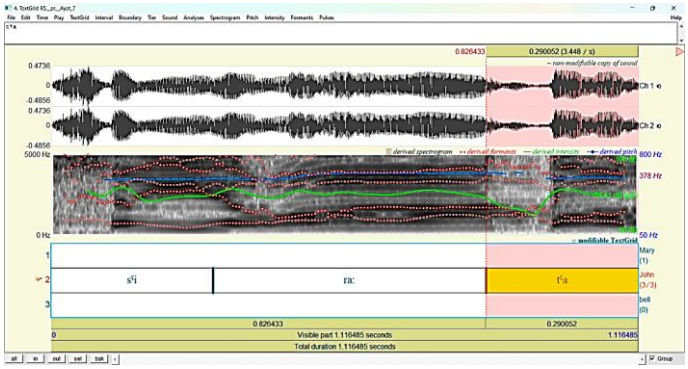
[47] Tareq Altalmas et al., "Quranic Letter Pronunciation Analysis Based on Spectrogram Technique: Case Study on Qalqalah Letters," in *Proceedings of the Special Tracks and Workshops at the 11th International Conference on Artificial Intelligence Applications and Innovations*, ed. Richard Chbeir et al., vol. 1539, CEUR Workshop Proceedings (Special Tracks and Workshops of AIAI 2015, Bayonne, France: CEUR, 2015), https://ceur-ws.org/Vol-1539/#paper2.

[48] Rachel Hayes-Harb and Kristie Durham, "Native English Speakers' Perception of Arabic Emphatic Consonants and the Influence of Vowel Context," *Foreign Language Annals* 49, no. 3 (September 2016): 557–72, https://doi.org/10.1111/flan.12217.

Spectrograms 9 and 10 show an annotation for NNS males' pronunciation of the /tˤ/ in verse 7. The pronunciation duration of PM-1 was shorter than that of PM-2, showing relatively similar results to the pronunciation values of the /tˤ/ in verse 6. However, the key difference lies in the duration of the /tˤ/ in verse 6, which was shorter due to a briefer articulation of the vowel /a/. Additionally, the frequency of the produced sound differed significantly from that of the /tˤ/ in verse 6. The frequencies of PM-1 and PM-2 were 248.8 Hz and 257 Hz, respectively, exceeding the typical male frequency range of 60-240 Hz. This was due to the overemphasized pronunciation of the /tˤ/, resulting in a higher-than-usual pitch. Regarding the intensity, PM-1 exhibited a lower intensity than PM-2, with values of 72 dB and 74.1 dB, respectively. Both values fall within the average intensity communicative range of communication, which is 66-75 dB.[49]



Spectrogram 11. Visualization of the Pronunciation of /tˤ/ in the Word /sˤira:tˤa/ verse 7 by PF-1



Spectrogram 12. Visualization of the Pronunciation of /tˤ/ in the Word /sˤira:tˤa/ verse 7 by PF-2

Spectrograms 11 and 12 present annotations of non-native female speakers' (NNS females) pronunciation of the phoneme /tˤ/ in verse 7. The pronunciation durations of PF-1 and PF-2 were 0.229 s and 0.290 s, respectively, shorter than the pronunciation duration of the /tˤ/ in verse 6. Furthermore, the F0 of PF-1 was

[49] Ettien Koffi, "A Comprehensive Review of Intensity and Its Linguistic Applications," *Linguistic Portfolios* 9, no. 1 (March 24, 2020), https://repository.stcloudstate.edu/stcloud_ling/vol9/iss1/2.

lower than that of PF-2, recorded at 350.3 Hz and 378 Hz, respectively, indicating a very high pitch. Meanwhile, the intensity levels in this verse were similar to those recorded in verse 6. The intensity levels for PF-1 and PF-2 in this verse were 74.5 dB and 74.41 dB, aligning with the ideal intensity range for NNS females, which is 73.54–84.99 dB.[50]

Table 4. Acoustic Data of /tˤ/ Pronunciation in The Word /sˤiraːtˤa/ verse 7

Participant	Duration (s)	Pitch (Hz)	Intensity (dB)	F1	F2	F3
NS-M	0.252	159.5	74.45	676.6	1012.3	2923.6
NS-F	0.312	215.8	80.26	707.6	1212.8	3065.8
PM-1	0.278	248.8	72	704.0	1342.7	2759.7
PM-2	0.329	257	74.1	754.4	1372.4	2803.7
PF-1	0.229	350.3	74.5	851.9	1269.8	2969.2
PF-2	0.290	378	74.41	971.5	1438.1	3243.2

Table 4 presents the acoustic analysis of /tˤ/ in /sˤiraːtˤa/ verse 7, where NS-M has a shorter duration, lower F0, and higher intensity compared to NNS males, while the NS-F has a longer duration compared to the NNS females. Furthermore, both NS-M and NS-F exhibit lower F0 values and higher intensity levels. The pronunciation patterns of native speakers (NS) closely resemble those of NNS speakers, supporting Ali et al.'s observation that the duration differences between NS and Sundanese NNS are not significantly large.[51] Furthermore, male NNS speakers exhibit longer pronunciation durations than females, corroborating the findings of Alsuhaim.[52]

In term of pitch, the F0 of both NS-M and NS-F is lower than that of NNS, similar to the /tˤ/ pronunciation in verse 6. Among the NNS, males exhibit lower frequencies than females. However, the F0 values of NNS males exceed the ideal frequency range, creating an exaggerated elevation characteristic. In contrast, the F0 values of NNS females remain within the ideal range. This overemphasis in pronunciation likely reflects phonological interference from NNS attempting to overadapt their articulation of Arabic phonemes.

The intensity levels of both NS-M and NS-F are generally comparable to NNS, except for a slight decrease in the /tˤ/ pronunciation in verse 6. Both NNS males and females demonstrate identical intensity values, aligning with the communication intensity range for NNS 66-75 dB. The strength of vocal intensity is

[50] Farzad Izadi et al., "Determination of Fundamental Frequency and Voice Intensity in Iranian Men and Women Aged Between 18 and 45 Years," *Journal of Voice* 26, no. 3 (May 1, 2012): 336–40, https://doi.org/10.1016/j.jvoice.2011.05.008.

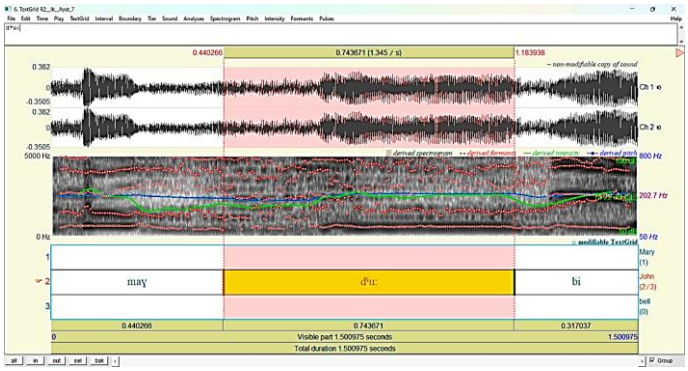
[51] Mad Ali et al., "Investigating the Arabic /f/ Pronunciation: A Comparative Analysis of Acoustic Phonetics," *Al-Ta'rib : Jurnal Ilmiah Program Studi Pendidikan Bahasa Arab IAIN Palangka Raya* 11, no. 2 (December 8, 2023): 181–96, https://doi.org/10.23971/altarib.v11i2.7234.

[52] Wasmiah Alsuhaim, "Gender Differences in the Acquisition of the VOT of English Bilabial Stops among Saudi ESL Learners," *Journal of Language and Linguistic Studies* 18, no. 0 (January 12, 2022), https://www.jlls.org/index.php/jlls/article/view/3221.

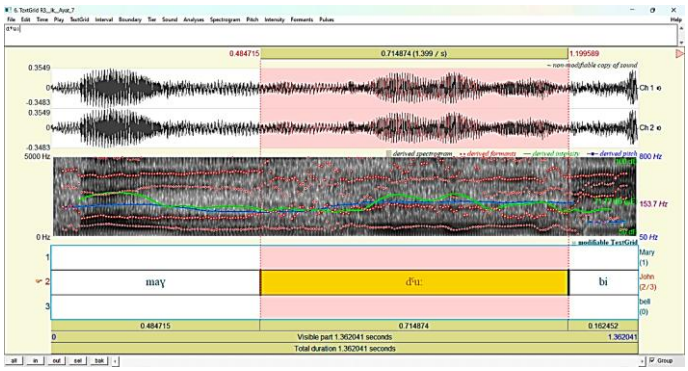
influenced by sociolinguistic factors, particularly the soft-spoken communication style of Sundanese speakers. Tables 3 and 4 indicate that NNS males exhibit shorter articulation durations, lower F0, and lower intensity than NNS females. Acoustically, the NNS males' pronunciation is closer to NS than the NNS females' pronunciation. This similarity is reflected in their shorter articulation duration, lower F0, and formant values F1, F2, and F3 closer to NS-M phonetic characteristics. In contrast, NNS females tend to have longer durations, higher F0, greater intensity, and higher F1, F2, and F3 values, which differ from the pronunciation pattern of the NS-F.

Spectrographic Analysis of the/dˤ/ Phoneme by Non-Native Speakers

The following shows a spectrogram as an illustration of the phonetic review of NNS pronouncing phonemes /dˤ/ in the word /almaɣdˤu:bi/ and /adˤdˤa:lli:n/.



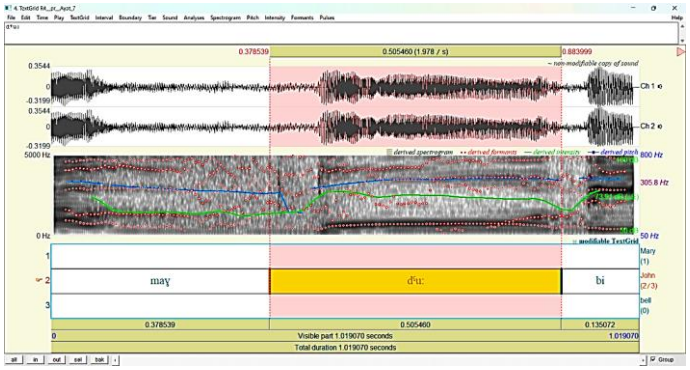
Spectrogram 13. Visualization of the Pronunciation of /dˤ/ in the Word /almaɣdˤu:bi/ by PM-1



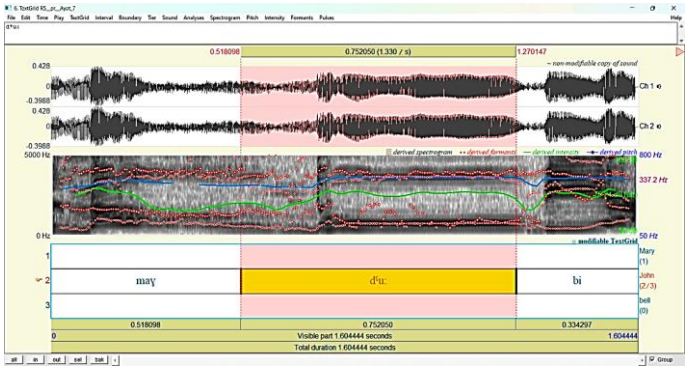
Spectrogram 14. Visualization of the Pronunciation of /dˤ/ in the Word /almaɣdˤu:bi/ by PM-2

Spectrograms 13 and 14 illustrate NNS males'/dˤ/pronunciation in the word /almaɣdˤu:bi/. The articulation duration for PM-1 is 0.743 s, longer than PM-2, which produced it in 0.714 s. These values differ significantly from the findings of Faiqoh & Masrukhi stating that the average duration of a long vowel (mad ṭabīʿī)

pronounced by male speakers is 0.580 s.[53] A notable frequency difference is observed between PM-1 and PM-2, with F0 values of 202.7 Hz and 153.7 Hz, respectively. The higher frequency of PM-1 indicates a significant difference in vocal characteristics compared to PM-2. Regarding intensity, PM-1 produces a stronger sound at 74.22 dB, compared to PM-2 at 71.77 dB. This finding aligns with the research of Gelfer & Young, who suggest that male speakers generally produce higher vocal intensity.[54]



Spectrogram 15. Visualization of the Pronunciation of /dˤ/ in the Word /almaɣdˤu:bi/ by PF-1



Spectrogram 16. Visualization of the Pronunciation of /dˤ/ in the Word /almaɣdˤu:bi/ by PF-2

Spectrograms 15 and 16 show an analysis of the /dˤ/ pronunciation in the word /almaɣdˤu:bi/ by NNS females. The articulation duration for PF-1 is shorter than PF-2, measured at 0.505 s and 0.752 s, respectively. The duration of PF-2 is closer to the average duration of long vowel pronunciation by female speakers, which is 0.645 s. Regarding frequency, PF-1 produced a lower F0 of 305.8 Hz, while PF-2 reached 337.2 Hz. This difference is attributed to PF-2 employing a higher

[53] Muflihana Dwi Faiqoh and Moh. Masrukhi, "Penerapan Fonetik Akustik Dalam Bacaan Mad Alquran (Studi Kasus Pada Qiraat Qari Internasional)," *Jurnal CMES* 12, no. 1 (October 9, 2019): 29, https://doi.org/10.20961/cmes.12.1.34869.

[54] Marylou Pausewang Gelfer and Shannon Ryan Young, "Comparisons of Intensity Measures and Their Stability in Male and Female Sneakers," *Journal of Voice* 11, no. 2 (June 1997): 178–86, https://doi.org/10.1016/S0892-1997(97)80076-8.

vocal intonation. Meanwhile, the sound intensity levels recorded for PF-1 and PF-2 were 73.91 dB and 75.24 dB, respectively, falling within the ideal intensity range for NNS females, 72.4–78.7 dB.

Table 5. Acoustic Data of /dˤ/ Pronunciation in The Word /almaɣdˤu:bi/

Participant	Duration (s)	Pitch (Hz)	Intensity (dB)	F1	F2	F3
NS-M	0.335	165.1	80.38	378.8	1131.3	3071.7
NS-F	0.572	234	78.53	467.5	745.2	2997.2
PM-1	0.743	202.7	74.22	664.4	1782.2	3094.7
PM-2	0.714	153.7	71.77	582.4	1638.0	2937.4
PF-1	0.505	305.8	73.91	620.4	1702.4	3168.9
PF-2	0.752	337.2	75.24	627.6	1227.9	3363.4

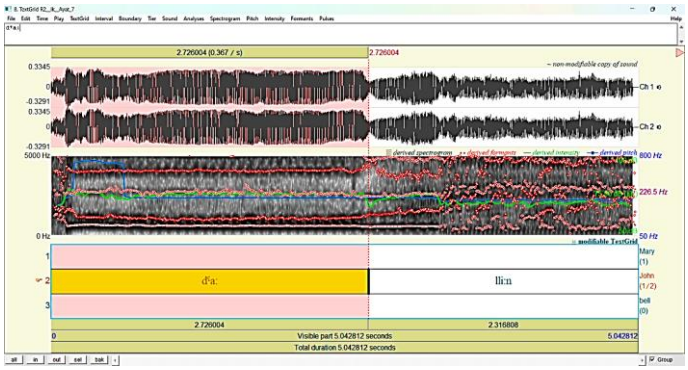
Table 5 presents the acoustic analysis of /dˤ/ in /almaɣdˤu:bi/. This word contains a long vowel, resulting from ḍammah diacritic on the /dˤ/, followed by a sukūn wau, which is prolonged for two harakat, affecting /dˤ/ duration.[55] Both NS-M and NS-F produce shorter durations than NNS, which tend to prolong sounds due to vowel extension and mother tongue interference, especially among Sundanese speakers. NNS males produce longer durations than females, aligning with Pranoto's finding. This variation suggests that language background, local accents, and gender influence sound duration. Specifically, NNS speakers, such as Sundanese speakers, tend to pronounce the /dˤ/ longer than NS.

The F0 value of NS-M and NS-F is lower than that of NNS, aligning with Mutmainnah et al., who noted that NS tends to have a lower F0 value than NNS. The higher frequency in NNS, particularly in PM-1, is due to the excessive vocal effort in adapting the pronunciation of the /dˤ/ more distinctly, indicating stronger vocal output. The frequency values recorded for each participant fall within the ideal range.

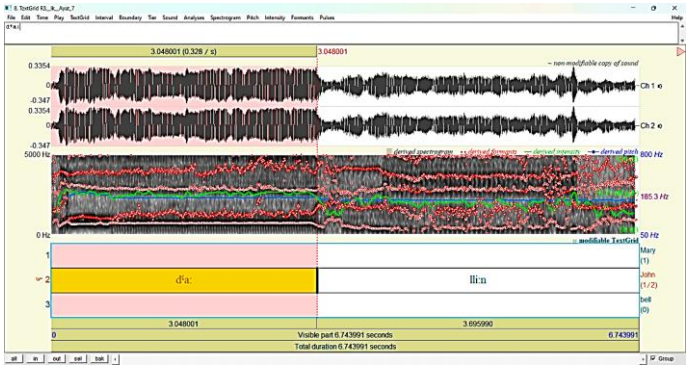
Both NS-M and NS-F exhibited higher intensity than NNS, indicating NS's stronger articulation of the /dˤ/, consistent with the elevation characteristic. This difference might stem from NNS' background as Sundanese speakers, who tend to have a softer communication style. Among NNS, male speakers have lower intensity than female speakers, contradicting Gelfer & Young's findings. Additionally, F1, F2, and F3 values indicate that NS have lower formant frequencies than NNS, which is lower than the average adult formant values.[56] This suggests a difference in tongue positioning during /dˤ/ articulation among NNS.

[55] Abdullah Abdul Qadir Hiluz, *Al-Muyassar Al-Mufid Fi 'Ilm at-Tajwid* (Mamlakah Al-Urduniyah Al-Hasyimiyah, 2008).

[56] Syarifah N. S. Badaruddin et al., "Analysis of Formant Frequencies of the Correct Pronunciation of Quranic Alphabets Between Kids and Adults," *Middle-East Journal of Scientific Research* 25, no. 6 (2017), https://idosi.org/mejsr/mejsr25(6)17.htm.

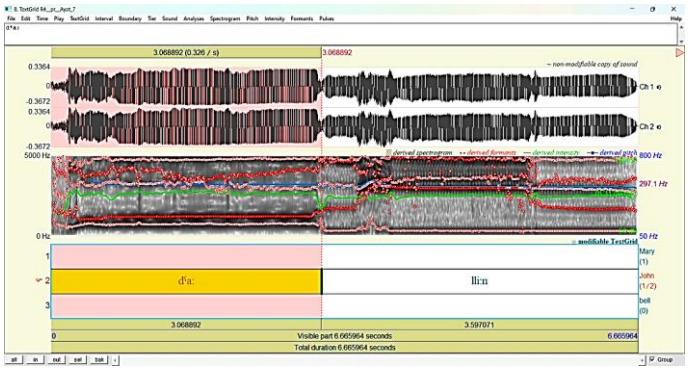


Spectrogram 17. Visualization of the Pronunciation of /dˤ/ in the Word /adˤdˤa:lli:n/ by PM-1

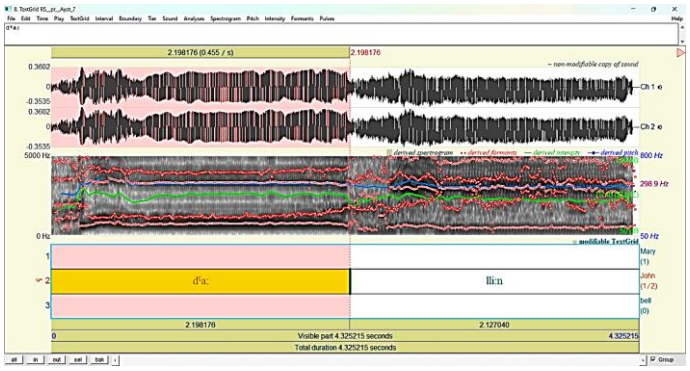


Spectrogram 18. Visualization of the Pronunciation of /dˤ/ in the Word /adˤdˤa:lli:n/ by PM-2

Spectrograms 17 and 18 illustrate the pronunciation of the /dˤ/ in the word /adˤdˤa:lli:n/ by NNS males. The duration of articulation produced by PM-1 and PM-2 is 2.726 s and 3.048 s, respectively. These values differ from Faiqoh & Masrukhi's findings, which state that the average duration of the /dˤ/ in mad lāzim mutsaqqal kilmī for NNS males is 2.330 s. The F0 for PM-1 is 226.5 Hz, while for PM-2, it is 185.3 Hz. Although these frequencies appear relatively high, they remain fall within the ideal range for male participants. Regarding the intensity, PM-1 produces a sound intensity of 75.96 dB, while PM-2 reaches 75.71 dB. These findings align with Pranoto's, which states that the typical intensity range for male voices is 72-83 dB.



Spectrogram 19. Visualization of the Pronunciation of /dˤ/ in the Word /adˤdˤa:lli:n/ by PF-1



Spectrogram 20. Visualization of the Pronunciation of /dˤ/ in the Word /adˤdˤa:lli:n/ by PF-2

Spectrograms 19 and 20 illustrate the pronunciation of the /dˤ/ in the word /adˤdˤa:lli:n/ by NNS females. The articulation duration for PF-1 is 3.068 s, whereas PF-2 lasts 2.198 s. Notably, only the duration of PF-2 closely aligns with the average pronunciation duration of the /dˤ/ in mad lāzim mutsaqqal kilmī for female speakers, which is 2.206 s. The F0 produced by PF-1 is 297.1 Hz, while PF-2 reaches 298.9 Hz. These values indicate that NNS females use a relatively high pitch but remain within the ideal frequency range. Regarding sound intensity, NNS females produce an intensity of 76.31 dB for PF-1 and 75.46 dB for PF-2, which falls within the intensity range for NNS females.

Table 6. Acoustic Data of /dˤ/ Pronunciation in The Word /adˤdˤa:lli:n/

Participant	Duration (s)	Pitch (Hz)	Intensity (dB)	F1	F2	F3
NS-M	3.598	134.7	82.51	641.9	966.0	3201.4
NS-F	4.260	218.1	83.17	610.8	1055.9	3030.9
PM-1	2.726	226.5	75.96	637.5	1114.6	2701.0
PM-2	3.048	185.3	75.71	712.8	1283.0	2884.7
PF-1	3.068	297.1	76.31	709.1	1206.7	3097.8
PF-2	2.198	298.9	75.46	756.7	1277.6	3245.7

Table 6 presents the acoustic data pronunciation of the /dˤ/ in the word /adˤdˤa:lli:n/. In this word, the tajweed rule of mad lāzim mutsaqqal kilmī applies to the /dˤ/. This rule falls under the category of long vowels, requiring a duration of six harakat, which influences the pronunciation length of the /dˤ/. The analysis reveals that both NS-M and NS-f have a longer pronunciation duration than NNS, demonstrating that NS maximizes fluency and consistency in applying the mad lāzim mutsaqqal kilmī rule. In contrast, NNS tend to have a shorter pronunciation duration, although their pronunciation remains within the average range for mad lāzim mutsaqqal kilmī. Furthermore, a gender-based comparison between NNS males and females indicates that males tend to have a longer pronunciation duration.

Based on the data above, the voice frequency of NS-M and NS-F is lower than that of NNS. The higher frequency in NNS suggests using an exceptionally elevated

voice to maximize the strong elevation characteristic more distinctly. The frequencies produced by NNS still fall within the acceptable range.

The voice intensity of NS-M and NS-F is higher than that of NNS, demonstrating NS's proficiency in pronouncing the /dˤ/ with a strong sound, a characteristic of elevation sound. This comparison aligns with Al-Raba'a's findings. As shown in Table 6, the intensity levels of NS males and females are comparable. The lower F1, F2, and F3 values in NS compared to NNS indicate superior articulation and tongue positioning in producing the elevation feature of /dˤ/. These results contrast with Zaelany, who reported that the F1 range for the /dˤ/ falls between 341-490 Hz, while F2 ranges from 1296-1768 Hz.[57] Furthermore, when comparing F1, F2, and F3 values, NNS males exhibited lower values than NNS females. Taken together, the findings from Tables 5 and 6, indicate that NNS males exhibit a longer duration, lower F0, and smaller F1, F2, and F3 values than NNS females. Based on acoustic analysis, NNS males demonstrate pronunciation characteristics that closely resemble NS-M more than NNS females.

Conclusion

This study analyses the spectrographic characteristics of the phonemes /tˤ/ and /dˤ/ in the recitation of Al-Fatihah by NNS, specifically Ummi teachers as Sundanese speakers, and compares them with NS. The findings indicate that in the articulation of the phoneme /tˤ/, NS exhibits a shorter duration, a lower fundamental frequency, and a higher intensity than NNS. These characteristics suggest that NS can maximize the phonetic properties of the elevation phonemes. Conversely, NNS tends to produce a longer duration, a higher F0, and a lower intensity. A distinct pattern emerges in the articulation of /dˤ/: NS display a longer duration, lower F0, and higher intensity, reflecting consistent and fluent pronunciation. NNS, however, demonstrate a shorter duration, higher F0, and lower intensity, possibly influenced by first language interference and the presence of a long vowel following the /dˤ/ phoneme.

Differences are also observed based on gender, where NNS males exhibit a shorter duration and a lower F0 than NNS females. Despite these variations, the pronunciation of NNS closely approximates that of NS in terms of formant patterns, indicating an effort to adapt to the phonetics of the Arabic language. Overall, the findings of this study suggest that NNS males are more closely aligned with NS pronunciation patterns than female speakers in terms of duration, frequency, intensity, and formant characteristics. These findings provide valuable insights for tajweed instruction and offer a foundation for spectrographically informed evaluation of Qur'anic recitation among non-native speakers.

[57] Muchamad Novel Zaelany, "Analisis Dan Karakterisasi Sinyal Konsonan Suara Manusia Berdasarkan Aspek," December 9, 2007, https://repository.uinjkt.ac.id/dspace/handle/123456789/11327.

Author Contribution Statement

As the primary author, SM designed the study, collected, processed, and analyzed the data, developed the background and literature review sections, and drafted the initial manuscript. MZ and NS, as academic supervisors, provided guidance on the methodology, reviewed the data analysis, and contributed to the scholarly refinement of the manuscript. ZT assisted in translating the manuscript. All authors collectively reviewed and approved the final manuscript, ensuring comprehensive oversight and scientific rigor throughout the research process.

Declaration of Competing Interest

The authors declare that no conflict of interest could influence the results or interpretation of the research presented in this article. All study aspects were conducted independently without any external pressure or influence.

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Biography of Authors

Siti Marya Ulpah is a student at Universitas Pendidikan Indonesia, specializing in Arabic Language Education. She is a bachelor's student at Universitas Pendidikan Indonesia, focusing on Arabic linguistics. Siti Marya Ulpah has extensive experience in linguistic studies, with a particular focus on Arabic phonetics and phonology. In addition to her research activities, she is actively involved in early childhood education, working as a homeschooling teacher. She can be contacted at maryaulpah04@upi.edu.

Mohamad Zaka Al Farisi is a lecturer at Universitas Pendidikan Indonesia, specializing in Arabic Language Education. He holds the academic title of Professor in Applied Arabic Linguistics from Universitas Pendidikan Indonesia. He is also a researcher at Universitas Pendidikan Indonesia, focusing on applied Arabic linguistics, pragmatics, and translation studies. He has extensive experience in applied linguistic research related to Arabic and Qur'anic translation studies. In addition, he is actively involved in teaching and mentoring postgraduate students, serving as Head of the Arabic Language Education study program at the Universitas Pendidikan Indonesia. He can be contacted at zaka@upi.edu.

Nalahuddin Saleh is a lecturer at Universitas Pendidikan Indonesia, specializing in Arabic Language Education. He holds a Master's degree in Islamic Studies with a concentration in Arabic Language from Universitas Islam Negeri Sunan Gunung Djati. He is a lecturer and researcher at Universitas Pendidikan Indonesia, focusing on Arabic phonology, language pedagogy, and Arabic linguistics. Nalahuddin Saleh has extensive experience in Arabic phonology and syntax, as well as in Islamic studies, with particular expertise in Arabic sound systems, sentence structure, and classical Islamic texts. With a specific focus on phonological analysis, language acquisition, and the development of instructional materials for non-native Arabic learners. In addition to his research, Nalahuddin Saleh is actively involved in teaching and mentoring undergraduate students, serving as a lecturer and academic advisor at Universitas Pendidikan Indonesia. He can be contacted at: nalahuddinsaleh@upi.edu.

Zalfa Tsania Rachman is an Albukhary International University student specializing in Media and Communication. She focuses on media production and public relations. She has extensive experience in various projects, particularly digital content creation, documentaries, and short movies. She can be contacted at zalfa.rachman@student.aiu.edu.my.