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Towards a Phonological Model of Intonation in Qassimi Arabic: An Acoustic Study

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***Abstract*—This study investigates the intonational patterns of Qassimi Arabic (QA), a dialect spoken in central Saudi Arabia, using the Autosegmental–Metrical (AM) framework. It identifies characteristic intonational contours in declarative and yes/no questions and compares these with patterns found in other Arabic dialects. Twenty native QA speakers (10 male, 10 female) participated by reading structured stimuli designed to elicit natural declarative and interrogative prosody. Acoustic analysis was conducted using Praat to examine fundamental frequency (F0) contours and boundary tones. Results indicate that declarative sentences in QA typically end with low boundary tones (L-L%, L%), while yes/no questions display rising contours (L-H%, H-H%). Statistical analysis confirmed that F0 values in interrogative sentences were significantly higher than those in declaratives across all speakers, regardless of gender. These findings align broadly with patterns observed in other Arabic dialects such as Hijazi, Egyptian, and Lebanese Arabic, while also revealing dialect-specific nuances in QA. This research contributes to the theoretical phonology of Arabic by expanding empirical coverage to a previously undocumented variety and supports the applicability of the AM framework in describing Arabic prosody.**

***Index Terms*—intonation, fundamental frequency (F0), pitch contour, autosegmental–metrical, Qassimi Arabic**

I. Introduction

Intonation, commonly referred to as the "melody" of speech, is a central prosodic feature that conveys meaning beyond the literal words used in spoken language. It involves the modulation of pitch—specifically, the fundamental frequency (F0)—which rises and falls throughout an utterance and plays a pivotal role in the phonological system of a language. F0 is measured in Hertz (Hz), reflecting the rate of vocal fold vibration and forming the acoustic basis of perceived pitch. As Arvaniti (2015, p. 2) notes, intonation constitutes "the linguistically structured and pragmatically meaningful modulation of F0." Similarly, O'Rourke (2012) explains that speech produces modulated sound waves perceived as pitch, which fluctuate across time and convey essential communicative cues. These patterns of intonation emerge early in human development, even before children produce actual words (Wells & Stackhouse, 2015).

Building upon its acoustic foundation, intonation serves numerous linguistic and communicative functions. It helps encode grammatical structure, sentence modality (e.g., distinguishing between statements and questions), pragmatic focus, speaker attitudes, and emotional states. Intonation functions like spoken punctuation, shaping interpretation and sentence type; for instance, a rising contour '*Really*↗' can signal a question or surprise, while a falling one '*Really*↘' may express certainty or disbelief (Roach, 2009; Nolan, 2008). Moreover, prosodic variation contributes to interpersonal dynamics by signaling enthusiasm, boredom, emphasis, or hesitation (Froemming, 2020). These rich functions highlight the interplay between intonation, grammar, and speaker intention.

While intonation is a universal feature of human language, its realization varies across languages and dialects, which has significant implications for phonological theory. Each language encodes its own distinctive intonational patterns, shaped by both linguistic and paralinguistic factors (Knis, 2004). In the case of Arabic, dialectal variation is particularly notable. For example, Iraqi Arabic exhibits a characteristic HL falling contour, whereas pitch declination is more prevalent in eastern dialects and less common in western varieties like Moroccan Arabic (Ghazali et al., 2007). This diversity underscores the need for localized analyses of intonation within individual dialects. The Autosegmental–Metrical (AM) framework has proven valuable for such analyses due to its structured and cross-linguistically applicable model of pitch representation. However, despite its utility, several dialects remain understudied—among them, Qassimi Arabic.

While Modern Standard Arabic (MSA) remains the formal written code, spoken Arabic is manifested in numerous regional dialects, each with its own distinct prosodic characteristics. Prior studies on Arabic intonation have

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documented a range of patterns in dialects such as Egyptian Arabic (El Zarka, 2011), Lebanese Arabic (Chahal, 2001), and Hijazi Arabic (Almbark, 2008). These studies have shown that, despite certain shared intonational tendencies, dialects often diverge in the realization of boundary tones and pitch accent types. Such differences are not only of phonological interest but also provide insight into regional identity and sociolinguistic variation.

Qassimi Arabic (QA), spoken in central Saudi Arabia, remains underexplored in intonational phonology despite its distinct phonetic features compared to dialects like Najdi or Hijazi. The absence of empirical studies on QA prosody limits our understanding of the full typological range of Arabic intonation systems and leaves a significant gap in the literature on dialectal Arabic.

This study aims to address this gap by providing a systematic analysis of intonational patterns in QA, focusing on two core sentence types: declarative sentences and yes/no questions. Using the AM framework, this research investigates how pitch contours in QA signal sentence modality and whether they conform to patterns observed in other Arabic dialects. The study employs acoustic methods to analyze fundamental frequency (F0) contours in controlled elicitation tasks with native QA speakers. The central research questions guiding this study are as follows:

1. What are the characteristic intonational patterns of declarative sentences and yes/no questions in Qassimi Arabic?
2. To what extent do these patterns align with or diverge from those observed in other documented Arabic dialects?

By answering these questions, the study contributes not only to the phonological documentation of an under-researched Arabic dialect but also to the broader field of intonational phonology. The findings are expected to enhance our understanding of prosodic variation within Arabic and offer empirical data that can inform typological comparisons and theoretical modeling.

This introduction outlines the study's scope, starting with intonation's linguistic role and the guiding theoretical model. Section 2 reviews related literature, Section 3 details the methodology, Section 4 presents results, Section 5 discusses them in relation to other Arabic dialects, and Section 6 concludes with key insights and broader implications.

Theoretical Framework

Two main schools of thought have shaped the study of intonation. The British school describes intonation based on pitch (F0) movements into contours like falling, high rising/falling-rising (pointed), low rising, falling-rising (rounded), and rising-falling (rounded), as well as compound tones like falling + low rising and rising-falling + low rising. Intonation groups in this model consist of four components: the prehead (unstressed syllables before the head or nucleus), head (from the first stressed syllable to the nucleus), nucleus (the main pitch-bearing element), and tail (syllables after the nucleus). For example, in "We were in a great hurry," the prehead is "we were in a," the head is "great," the nucleus is "hur-," and the tail is "-ry" (Grice et al., 2020).

In contrast, the American Structuralist school emphasized phonological structure, categorizing pitch into extra-high, high, mid, and low levels (Ladd, 2015). Pitch height was defined by their interrelations (Al Zaidi, 2018). This framework laid the foundation for Pierrehumbert's (1980) Autosegmental–Metrical (AM) approach, which is adopted in this paper.

Autosegmental–Metrical (AM) Model

The AM model, developed by Pierrehumbert (1980), evolved through three stages: distinguishing phonological from phonetic representation; linking intonation to communicative function (Pierrehumbert & Hirschberg, 1990); and establishing the ToBI transcription system (Beckman & Hirschberg, 1994).

Ladd (1996) coined the term "autosegmental–metrical" to describe the interaction between two phonological subsystems: an autosegmental tier for melodic tone and a metrical structure for prominence and phrasing (Arvaniti, 2015). In this model, tones are aligned with metrically strong syllables (Al Zaidi, 2018). Although the AM model was first designed for English, it has been successfully extended to other languages, including Korean (Jun, 1996), French (Jun & Fougeron, 1995), and Japanese (Venditti, 2005). Unlike earlier structuralist approaches that used multiple pitch levels, Pierrehumbert's model defines only two tonal targets—High (H) and Low (L)—which can combine into monotonal or bitonal pitch accents (e.g., H*+L). Figure 1 illustrates the phonological structural organization in greater detail.

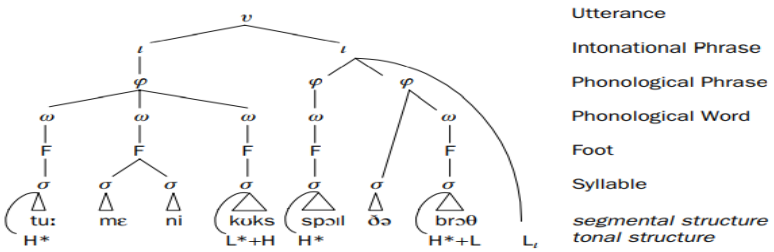

Figure 1. Phonological Structure of the English Proverb "Too Many Cooks Spoil the Broth" (Gussenhoven, 2004, p. 124)

Pierrehumbert (1980) proposed that intonation is compositional, meaning that an intonational contour can be broken down into three distinct elements: the pitch accent, the phrase accent (denoted by "–"), and the boundary tone (denoted by "%"). In this model, pitch is represented by two basic tonal categories—low (L) and high (H)—which define the shape of the F0 contour. Pierrehumbert and Hirschberg (1990) further identified six pitch accent types in English, including the simple tones H and L. The symbol H* indicates a high tone aligned with a stressed syllable, where the asterisk (*) marks the association with stress. Figure 2 illustrates the finite-state grammar framework used to generate intonational patterns in English.

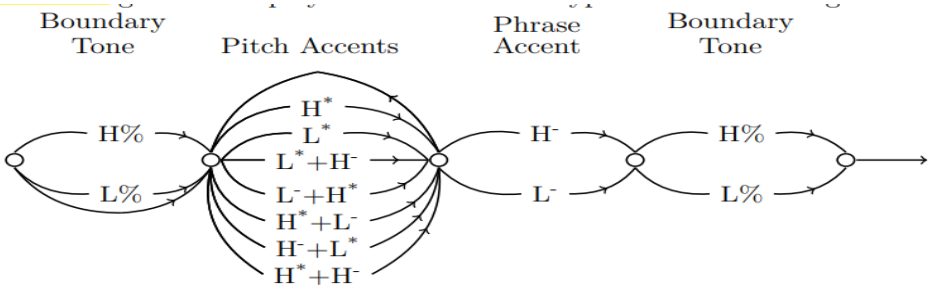

Figure 2. Finite-State Grammar for Generating Tunes of English Intonation (Pierrehumbert, 1980, p. 29)

The figure illustrates a typical American English intonation contour as proposed by Pierrehumbert (1980). In the linear AM model, each tone's realization depends on its identity, prosodic position, and preceding tone. Pierrehumbert (2000) modeled it as a finite-state automaton where pitch accents, phrase accents, and boundary tones generate varied intonation.

Ladd (2008) outlines four core principles of the AM model. First, sequential tonal structure refers to pitch being marked by local tonal events (e.g., H, L) aligned with specific segments, with pitch contours between them derived from transitions. Second, the model distinguishes pitch accent from stress, noting that while pitch accents often signal prominence, actual perceived stress can also depend on metrical or dynamic factors. Third, pitch accents and boundary tones are analyzed using just two basic tonal targets: High (H) and Low (L). Finally, global pitch trends result from localized adjustments, such as emphasis or utterance position, which affect tone scaling without altering H/L classification.

As Ladd (2008) summarizes, the AM model shares key principles with those used in this paper. First, it involves sequences of tonal structures (e.g., rising–falling), as in "He wrote the book," where pitch may rise on "wrote" or fall on "book." Second, pitch accents align with prominent syllables—for example, "wrote" is more or less prominent depending on the sentence type. Third, pitch accents are categorized as high (H) or low (L) tones, as illustrated in Figure 3.

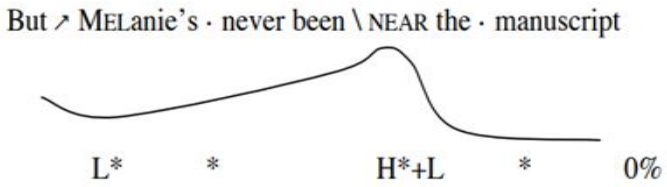

Figure 3. High Pitch Accent and Low Pitch Accent (Nolan, 2008, p. 6)

In Figure 3, the word "Melanie's" carries a low pitch accent followed by a high pitch accent on "NEAR", and as seen in the fourth element, F0 declination is suspended in questions, producing a rising contour as in "He wrote the book?".

The second stage of the AM framework, developed by Pierrehumbert and Hirschberg (1990), emphasizes that intonation conveys communicative functions, with the meaning of a contour emerging from its tonal components—pitch accent, phrase accent, and boundary tones—which together express the speaker's intent (Al Zaidi, 2018). For example, in American English:

1.a. "What about Anna? Who did she come with?"

b. "Anna came with MANNY" (Pierrehumbert, 1980, p. 266)

H* %

2. "It's even warm for December" (Pierrehumbert & Hirschberg, 1990, p. 296)

L+H* L H%

3. "Well, I'd like a Pavoni..." (Pierrehumbert, 1980, p. 291)

L* L* L*L H%

In the earlier examples, [H*] marks information focus (e.g., 1-b), [L+H*] signals contrastive focus (e.g., 2), and L* is linked to given or old information (e.g., 3). According to Asadu et al. (2019, pp. 46–47), the tones and symbols for the transcription of Intonation (see Appendix A).

The third stage in the AM framework saw the development of the ToBI (Tones and Break Indices) system, initially created to annotate American English intonation and later applied to other languages like German, Dutch, and Japanese. ToBI consists of four tiers, with required tiers for pitch contour (tones) and prosodic boundaries (break indices). Break indices are numbered: [0] indicates close cohesion (e.g., flapping), [1] reflects typical word-level juncture, [2] marks uncertain boundaries, [3] indicates intermediate phrase (ip) boundaries, and [4] signals intonational phrase (IP) boundaries. Optional tiers include orthographic transcription and miscellaneous notes for elements like disfluencies (Arvaniti, 2015).

II. Literature Review

Intonation, often referred to as the "music of speech," plays a critical role in shaping meaning across languages. It influences how speakers express attitudes, distinguish sentence types, and signal information structure. Despite its centrality in spoken communication, intonation has historically received less attention than other suprasegmental features (Asadu et al., 2019). This section reviews key literature on intonational patterns in declarative and interrogative sentences, first across global languages and then focusing on Arabic dialects. By identifying shared patterns and divergent features, this review establishes a foundation for the current study's focus on the under-researched intonation system of Qassimi Arabic (QA).

A. Intonational Patterns in World Languages

Across many languages, a fundamental distinction is observed between the intonation of declarative and interrogative sentences. Typically, declaratives exhibit falling intonation, while yes/no questions display rising contours. Lam (2017) demonstrates this distinction in Japanese, where the same syntactic structure can be interpreted as either a statement or a question depending solely on terminal pitch—falling for declaratives and rising for interrogatives.

Research in Spanish further reinforces this dichotomy. Portocarrero (2019), analyzing Ecuadorian Cuencano Spanish, observed a wide range of pitch accent types—especially bitonal ones like L+H* and H+L*—used to differentiate sentence types. Declaratives often included prenuclear L* L% contours or nuclear H+L* followed by L%, whereas yes/no questions exhibited a consistent L+H* HH% pattern, highlighting a clearer rising tendency in interrogatives.

In English, Hedberg et al. (2014) challenge earlier claims (e.g., Geluykens, 1988) that yes/no questions adopt falling contours. Using 410 real-life examples, they found that American English questions predominantly feature rising contours, especially L*H-H%, corroborating Portocarrero's findings in Spanish.

Cross-linguistic phonetic studies confirm these general trends that F0 is a reliable indicator of sentence type across languages. Lin et al. (2013) conducted a cross-linguistic phonetic study examining intonation through the acoustic cue F0. The study involved 12 native speakers—four each from Arabic, English, and Taiwanese Mandarin (six males and six females), aged 23 to 47—who read 28 sentences in their respective native languages. The results showed that yes/no questions consistently exhibited higher F0 values than declarative sentences, regardless of language background or whether the language was tonal or non-tonal.

However, some exceptions exist. Australian English, for example, exhibits rising intonation even in declarative sentences, especially among younger speakers and in informal settings. Fletcher and Loakes (2006) analyzed the intonational patterns of 17 speakers from Melbourne and rural Victoria using the ToBI framework. Their findings revealed that both statements and questions often employed high-rising terminals (H* H- L%) and final fall (H* L-L%), suggesting that intonational distinctions in Australian English are not strictly bound to sentence type. This variability underlines the need to examine intonation patterns dialect by dialect, especially in underexplored linguistic contexts like Arabic regional varieties.

B. Intonation in Arabic Dialects: A Regional Overview

Arabic dialects display both cross-dialectal similarities and notable differences in intonational behavior. A common theme is that declarative sentences tend to end in falling tones (e.g., L-L%), while yes/no questions are marked by rising contours (e.g., H-H%). Nevertheless, the specifics of pitch accents, boundary tones, and phrasing differ by region and sociolinguistic factors.

Arabic dialects, though sharing a common linguistic ancestry, show significant variation in their intonational systems. This section reviews studies on intonation in several Arabic varieties, starting with well-documented dialects such as Egyptian, Lebanese, Syrian, and Yemeni Arabic, which offer a broader view of regional intonational trends. It then shifts to Saudi dialects—Farasani, Hijazi, and Najdi Arabic—where recent research has revealed distinct pitch accent patterns and boundary tone behaviors. This general-to-specific structure provides a comparative framework for evaluating the Qassimi Arabic (QA) dialect.

Chahal and Hellmuth (2014) applied the AM framework to examine intonation in declarative and yes/no questions in Lebanese Arabic (LA) and Egyptian Arabic (EA). Their study involved seven educated urban LA speakers and fifteen EA speakers, using both read and quasi-natural speech. In both dialects, pitch accents were aligned with lexically stressed syllables. The results revealed a consistent L-L% (falling) contour for declaratives and an H-H% (high-rising) contour for yes/no questions. Pitch accents were consistently aligned with lexically stressed syllables, underscoring the

phonological role of stress in these varieties. Although the overall patterns were similar across both dialects, the gender of participants was not reported, and participant numbers were uneven, potentially affecting cross-dialectal comparisons.

The Damascene Arabic follows the general Arabic trend: declaratives have falling contours, while rising-falling bitonal patterns like LH*HLL%, and LH*L!H*L% appear in compound prosodic units, even in short phrases, showing that complex tonal combinations can serve discourse functions (Kulk et al., 2003).

Salem and Pillai (2020) examined the intonational patterns of the Taizzi variety of Yemeni Arabic (TYA). The study involved 30 female participants, aged 20–65, all of whom—and their parents—were born and educated in Taizz. Data were collected through a combination of read passages, 10 spontaneous conversations, 5 yes/no questions, and 5 wh-questions. Acoustic analysis using Praat revealed that the H*L% contour consistently appeared in both spontaneous speech and yes/no questions. In contrast, wh-questions were typically marked by the L*H% contour, highlighting a functional distinction in pitch movement between question types.

Abbas (2021) analyzed Farasani Arabic intonation, a variety spoken along the southwestern coast of Saudi Arabia. Using the AM model, the study examined the speech of seven native speakers. The findings revealed a diverse set of intonational patterns influenced by sentence structure. For instance, the prepositional phrases containing two words exhibited a rising pitch pattern (L H L%), while both subject and object clauses followed an L H* L% pattern. Farasani Arabic also displayed distinctive boundary tones: H% for continuation or surprise, !H% for alternative questions, HLH% for shocked expressions, and L% for both declaratives and wh-questions. These patterns contrast with those observed in Australian English by Fletcher and Loakes (2006), who found consistent use of mid-level tunes across sentence types, underscoring the cross-linguistic diversity of intonational systems. The presence of both L H L% and L H* L% configurations reveals a subtle pitch modulation strategy within clauses.

Al Zaidi (2018) investigated the intonational pattern of Hijazi Arabic (HA), specifically the Taif dialect, using a question–answer paradigm analyzed in Praat with 16 native speakers (aged 23–35). The study found that L+H* pitch accents were commonly used to mark focus, especially on left-dislocated elements. For example, in the sentence *Laila, Sami mar ams* 'Laila, Sami visited yesterday', the name *Laila* receives a bitonal L+H* accent, followed by postfocus compression on the remaining words. Declarative sentences consistently ended with a low boundary tone (L%). This study highlights that in Taif Arabic, a clear phonological strategy (i.e., intonation) rather than syntax, conveys informational focus, distinguishing it from structurally different dialects like those in central or northern Saudi Arabia.

Al Malki and Morrill (2016) explored the intonational and prosodic structure of yes/no questions in Urban Najdi Arabic (NA). The study involved eight native NA speakers (aged 19–30; four males and four females) studying at George Mason University. Using a picture-based elicitation task, participants produced 25 declarative sentences and five yes/no questions, which were analyzed using Praat and annotated with ToBI conventions. Results revealed two primary boundary tone patterns at the phrase-final edge: a high-rising contour (H-H%) and a fall-rise contour (L-H%). Words preceding H-H% demonstrated greater pitch excursion than those preceding L-H%, indicating a prosodic distinction between question types. This rising contour pattern for yes/no questions parallels findings in other languages, such as Ecuadorian Cuencano Spanish and American English (Portocarrero, 2019; Hedberg et al., 2014). However, generalization is limited due to the small sample size and the participants' residence in the U.S., which may introduce L2 influence from English (Kang, 2013).

In summary, studies reveal both universal and language-specific patterns in intonation: yes/no questions typically show rising contours, while declaratives tend to fall. Yet, dialectal variation shapes differences in pitch accents, boundary tones, and their interaction with stress and information structure. Despite rich research on many Arabic dialects, Qassimi Arabic (QA), a central Najdi variety, remains underexplored. Given its linguistic distinctiveness and social importance, this study fills the gap by analyzing the intonation of QA declaratives and yes/no questions. The findings aim to broaden our understanding of Arabic prosody and enrich cross-dialectal typological records.

III. Methodology

This study involved twenty native Qassimi Arabic speakers (10 males, 10 females; aged 20–40, median = 27), all born and raised in the Qassim region to Saudi parents and residing there at the time of data collection. Participants were selected based on regional and dialectal criteria. This section also outlines the stimuli and procedures used to elicit speech data, as well as the analytical methods employed to identify intonational patterns that may distinguish Qassimi Arabic from other varieties cross-linguistically.

A. Data Collection and Stimuli

Once participants were confirmed to meet the selection criteria, the researchers provided a detailed explanation of the study's purpose and procedures. Participants were informed that their recordings would be used exclusively for research, participation was voluntary, and they retained the right to withdraw at any stage without consequence. Written informed consent was obtained prior to data collection. Participants were provided with written sentences and asked to read them aloud in their native Qassimi dialect using different intonational forms.

Each utterance was produced twice—once as a declarative and once as a yes/no question. To elicit natural intonation, declaratives were framed as straightforward statements, while yes/no questions were posed to reflect inquiry. Participants first completed several practice trials to become familiar with the process. For instance, they were

presented with the following scenario: *Ahmad is 19 years old and saved his money for three years to buy a car. At the end of the year, he bought a black car*. Based on this context, participants were expected to produce the sentence *The color of Ahmad's car is black* first as a statement with falling intonation and then as a question with rising intonation, allowing for the observation of distinct pitch patterns in both forms. (See Appendix B for the complete set of elicited data).

Each participant was recorded individually in a quiet environment to ensure high audio quality, and each production was saved separately in WAV format. They read eight utterances, each repeated twice, resulting in a total of 320 recordings (8 sentences × 2 repetitions × 20 participants). Recordings were conducted using Praat and lasted approximately 30 minutes per participant. If a participant made an error or paused during reading, they were asked to repeat the sentence. Clarification and assistance were provided when needed to ensure consistent and natural intonation throughout the task.

B. Data Analysis

The recorded data were segmented and analyzed using Praat, a widely recognized tool for acoustic analysis (Boersma, 2001). The RTPITCH program was used when needed to verify intonational patterns. Sentences were imported into Praat, and Figure 4 illustrates a sample TextGrid used in the analysis.

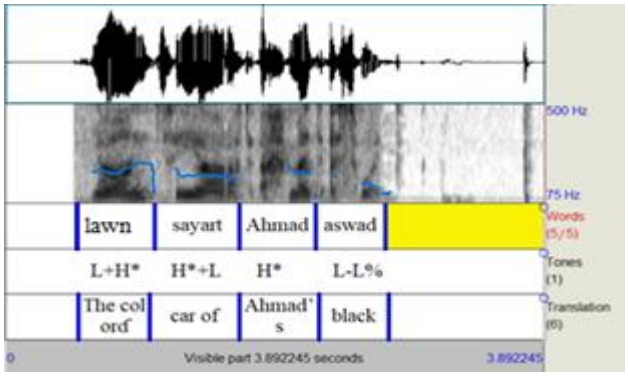

Figure 4. Example of a PRAAT TextGrid for "*The Color of Ahmad's Car Is Black*"

Following the AM approach, stressed syllables were identified to locate pitch accents (tones). As shown in Figure 4, Praat analysis was performed using a three-tier TextGrid: the first tier marked QA words, the second captured tonal events, and the third provided English translations (Al Zaidi, 2018). The F0 contour, visible in the spectrogram, was measured from start to end. Focus was placed on the tone tier to detect rising pitch at stressed syllables. For instance, *Lawn* 'color' showed an L+H* accent, *sayart* 'car' displayed H*+L, and *Ahmad* carried a high tone before the final fall, indicating a declarative contour.

C. Statistical Analysis

This section presents the statistical analysis conducted to evaluate differences in F0 values between the two repetitions for each participant. Mean F0 values were calculated and averaged to assess the consistency of intonation patterns and to identify any significant differences across participants. The analysis addresses the research questions outlined in Section 1. Quantitative data were processed using SPSS (version 25). Given the repeated nature of the data—each participant produced both declarative sentences and yes/no questions—a repeated-measures ANOVA was employed to examine within-subject variation (Hinkle et al., 2003). This test is appropriate for detecting differences in conditions applied to the same subjects. Additionally, descriptive statistics and paired-samples t-tests were used to provide further insight into mean differences between sentence types.

IV. Results

This section comprises four subsections, each focusing on a distinct aspect of the acoustic analysis. Subsection 4.1 details the descriptive statistics of F0 in declarative sentences, while Subsection 4.2 presents a parallel account for yes/no questions. Subsection 4.3 examines inferential statistics to determine significant F0 differences between sentence types. Finally, Subsection 4.4 summarizes key findings and their relevance to the study's research questions.

A. F0 Values of Declarative Sentences

The data representing declarative sentences were elicited through four utterances: *Lawn sayarat Ahmad aswad* 'The color of Ahmad's car is black', *Al-jaw be-Faransa bared* 'The weather in France is cold', *Khaled mudares* 'Khaled is a teacher', and *Eman ta-xsˁsˁ-t Rjadˁjat* 'Eman specialized in mathematics'. The acoustic results of these declarative sentences, as produced by all 20 participants, are summarized in Table 1.

TABLE 1
ENTIRE AVERAGES AND STD. DEVIATIONS OF THE FOUR DECLARATIVE SENTENCES BY ALL PARTICIPANTS

Declarative	Mean	Min.	Max.	Std. Dev.
1	144.91 Hz	100.60 Hz	221.80 Hz	35.470 Hz
2	135.53 Hz	95.00 Hz	202.30 Hz	33.750 Hz
3	144.55 Hz	86.50 Hz	213.20 Hz	37.137 Hz
4	148.38 Hz	104.60 Hz	221.60 Hz	35.410 Hz
Average	143.34 Hz	96.68 Hz	214.73 Hz	
Ring			118.05 Hz	

Table 1 presents the overall means, standard deviations, and the minimum and maximum F0 values for the four declarative utterances. As illustrated, the final words across all sentences showed consistent F0 patterns, indicating a stable intonational contour marked by L-L% and L% boundary tones.

B. F0 Values of Yes/No Questions

Similar to the declarative data, the same sentence structures were used in interrogative form to examine the intonational patterns of yes/no questions. These included: *Lawn sayarat Ahmad aswad?* 'The color of Ahmad's car is black?', *Al-jaw be-Faransa bared?* 'The weather in France is cold?, *Khaled mudares?* 'Khaled is a teacher?', and *Eman ta-xsˤsˤ-t Rjadˤjat?* 'Eman specialized in mathematics?'. Table 2 summarizes the F0 values for all four interrogative utterances as produced by participants, including the overall means, standard deviations, and the minimum and maximum F0 ranges.

TABLE 2
ENTIRE AVERAGES AND STD. DEVIATIONS OF THE FOUR YES/NO QUESTIONS BY ALL PARTICIPANTS

Yes/No Question	Mean	Min.	Max.	Std. Dev.
1	169.41 Hz	99.50 Hz	274.90 Hz	51.387 Hz
2	160.76 Hz	103.20 Hz	226.40 Hz	43.986 Hz
3	152.64 Hz	94.80 Hz	216.50 Hz	40.282 Hz
4	162.85 Hz	102.70 Hz	231.00 Hz	40.837 Hz
Average	161.41 Hz	100.05 Hz	237.20 Hz	
Ring			137.15 Hz	

As shown in the table, the interrogative structures consistently exhibited rising intonation patterns, reflected in the boundary tones L-H%, H%, and H-H%. The results indicate that the mean F0 of yes/no questions (137.15 Hz) was notably higher than that of declarative sentences (118.05 Hz). Additionally, the overall average F0 for yes/no questions exceeded that of declaratives, reinforcing the pattern of pitch elevation associated with interrogative intonation.

C. Differences Between Declarative and Yes/No Forms

This section presents the differences of the overall means, standard deviations, and the minimum and maximum F0 values for the four declarative and four yes/no questions, based on data from all 20 participants. To assess whether the differences in F0 values between declarative sentences and yes/no questions were statistically significant, both ANOVA and paired-samples t-tests were conducted. Table 3 presents the descriptive statistics for each sentence type, followed by the results of the ANOVA, which quantify the extent of variation attributable to sentence type.

TABLE 3
DESCRIPTIVE STATISTICS AND ONE-WAY ANOVA SUMMARY FOR F0 IN DECLARATIVE SENTENCES AND YES/NO QUESTIONS

Sentence Type	Count	Mean F_0 (Hz)	SD	Variance	Sum
Declarative	4	143.34	5.49	30.09	573.37
Yes/No Question	4	161.41	6.91	47.81	645.66

Source of Variation	SS	df	MS	F value	p value	Fcrit
Between Groups	653.140	1	653.140	16.770	0.006	5.987
Within Groups	233.678	6	38.946			
Total	886.818	7				

In addition to the ANOVA, paired-samples t-tests were conducted to further investigate the mean differences between sentence types (i.e., declarative and yes/no questions). These tests were used to determine whether the differences in average F0 values across the four structures for each sentence type were statistically significant, offering complementary evidence to support the ANOVA findings.

TABLE 4
PAIRED-SAMPLE T TEST RESULTS COMPARING F_0 VALUES OF DECLARATIVE SENTENCES AND YES/NO QUESTIONS ACROSS FOUR SENTENCE STRUCTURES

Declarative and Yes/No Questions	Paired Differences	Std. Dev.	Std. Error Mean	95% Confidence Interval of the Difference				
	Mean			Lower	Upper	t	*p*	Correlation
1	-24.500	34.658	7.750	-40.720	-8.820	-3.161	0.005	0.740
2	-25.223	28.049	6.272	-38.350	-12.095	-4.022	0.001	0.770
3	-8.090	18.453	4.126	-16.726	0.546	-1.961	0.065	0.889
4	-14.473	23.045	5.153	-25.258	-3.687	-2.809	0.011	0.827

Tables 3 and 4 examine whether sentence type influences F0 in Qassimi Arabic by presenting the results of both ANOVA and paired-samples t-tests. ANOVA and t-tests confirmed that yes/no questions (M = 161.41 Hz) had significantly higher F0 values than declaratives (M = 143.34 Hz), F = 16.77, p = .006. Most sentence pairs (1, 2, and 4) showed significant differences, supporting a consistent intonational contrast. Minor variation in Sentence 3 reduced significance (p = .065) but did not alter the overall pattern.

D. Paired-Sample T Test Results by Gender

To validate the general findings and explore potential gender-based variation, the paired-samples t-test was conducted separately for male and female participants. This analysis aimed to determine whether there were statistically significant differences in F0 values between declarative sentences and yes/no questions within each gender group. The test was run for the 10 male and 10 female participants individually. This gender-specific analysis provides insight into whether intonational patterns are consistent across genders or reflect sociophonetic variation within the Qassimi dialect.

The paired-samples t-test was conducted comparing F0 values between declarative sentences and yes/no questions for 10 male Qassimi Arabic speakers. The data reveal statistically significant differences in Sentences 2 and 3 (p = .020 and p = .030, respectively), indicating higher pitch in interrogatives. Sentence 1 and 4 approached (p = .105) and (p = .175), respectively. Correlation values ranged from weak to moderate (r = .169–.737), suggesting some variability in how consistently male speakers distinguished sentence types via pitch. Overall, the results partially support intonational differences in male speakers as shown in Figure 5.

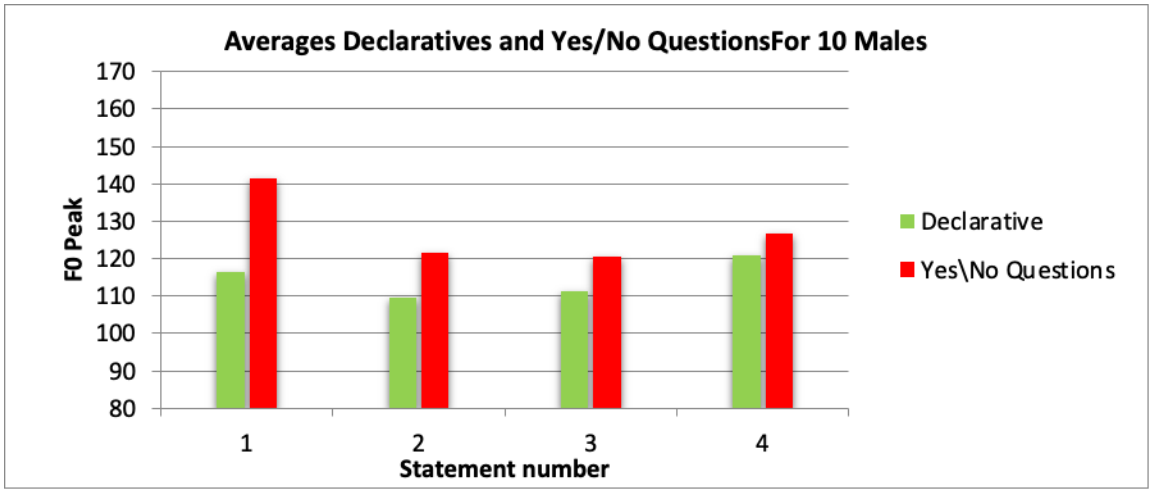

Figure 5. Mean F0 Values for Declarative Sentences and Yes/No Questions Across Four Statements by 10 Male Speakers

Figure 5 shows average F0 peak values for declarative and yes/no questions across four sentence types by 10 male speakers. In all cases, red bars (yes/no questions) exceeded green bars (declaratives), indicating a consistent rising pattern in interrogatives. Sentences 2 and 3 had the largest differences (−11.91 Hz, −9.35 Hz), both significant (p = .020, p = .030). Sentences 1 and 4 showed noticeable differences (−25.09 Hz, −5.75 Hz) but lacked significance (p = .105, p = .175), likely due to high variability (SD = 44.01, 12.35). Overall, yes/no questions consistently showed higher pitch.

For female speakers, paired-sample t-tests compared F0 values across four sentence pairs. Sentences 1, 2, and 4 showed significant differences (p < .05), confirming higher pitch in yes/no questions. Sentence 3 showed no significance (p = .394), likely due to pitch variability. The strongest contrast was in Sentence 2 (t = -3.691, p = .005). These results support the consistent use of higher F0 in interrogatives among female speakers.

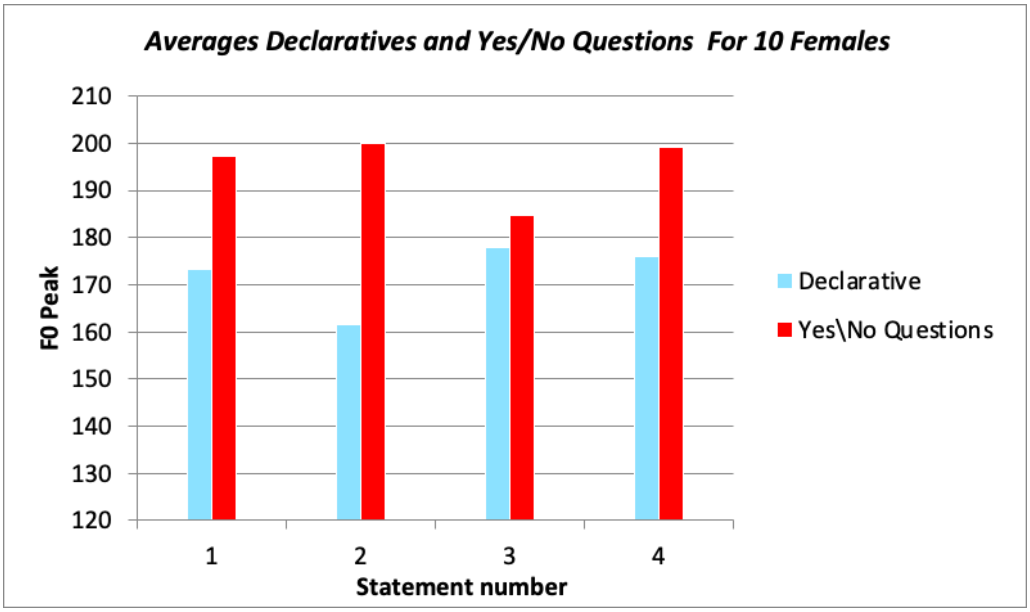

Figure 6. Average Values for Declaratives and Yes/No Questions in 10 Female Speakers

Figure 6 shows average F0 peak values for declarative and yes/no questions across four sentence types by 10 female speakers. In all cases, red bars (questions) exceed blue bars (declaratives), confirming a rising intonation pattern in interrogatives. Sentence 2 shows the largest mean difference (−38.54 Hz), followed by Sentences 1 (−23.91 Hz) and 4 (−23.20 Hz), all statistically significant ($p = .005, .013, .029$). Sentence 3 shows a smaller difference (−6.83 Hz) and is not significant ($p = .394$), likely due to high variability (SD = 24.15). Overall, yes/no questions consistently show higher pitch, though significance varies by consistency and effect size.

In summary, the acoustic and statistical analyses confirm a robust intonational distinction between declarative sentences and yes/no questions in Qassimi Arabic. Among the 20 native speakers, yes/no questions consistently exhibited higher mean F_0 values (M = 161.41 Hz; range: 100.05–237.20 Hz) than declaratives (M = 143.34 Hz; range: 96.68–214.73 Hz), with a significant overall difference supported by ANOVA ($F(1, 6) = 16.77$, $p = .006$). Paired-sample t-tests further confirmed this trend, with significant contrasts in most sentence pairs, particularly Sentences 1, 2, and 4. Tonal analysis showed that declaratives typically ended with low boundary tones (L-L% or L%), while yes/no questions were marked by rising contours (L-H%, H%, or H-H%). Occasional deviations (e.g., H%, H-L%, H*+L%) appeared in both sentence types, likely reflecting speaker-specific variation or repetition-based shifts. Although statistical significance was limited in Sentence 4 (males) and Sentence 3 (females), both genders consistently followed the same pitch trend, reinforcing that Qassimi Arabic systematically encodes interrogativity through rising intonation.

Although statistical significance weakened in some cases—such as Sentence 4 for males and Sentence 3 for females—this likely reflects increased within-group variability rather than a shift in the overall trend. Female speakers consistently showed higher F0 values across sentence types, attributable to physiological differences in vocal fold structure. Their shorter, thinner vocal folds vibrate more rapidly, producing higher pitch levels (Lee & Martinez, 2025). Overall, the findings indicate that Qassimi Arabic marks interrogativity through consistent rising intonation, in line with autosegmental–metrical tonal frameworks.

V. Discussion

This study sought to investigate the characteristic intonational patterns of declarative sentences and yes/no questions in Qassimi Arabic (QA), a dialect from central Saudi Arabia, within the Autosegmental-Metrical (AM) framework. Specifically, it aimed to determine whether intonational contours in QA conformed to trends observed in other Arabic dialects and to identify dialect-specific tonal features.

The acoustic analysis revealed a clear prosodic distinction between declarative and yes/no question forms. Declarative sentences consistently concluded with falling intonation contours, predominantly marked by low boundary tones such as L-L% and L%. This finding is aligned with established patterns in Arabic dialects including Egyptian Arabic (Chahal & Hellmuth, 2014), Lebanese Arabic (El Zarka, 2011), and Hijazi Arabic (Al Zaidi, 2018), where falling boundaries are used to mark declaratives. The total F0 mean for declaratives in this study was 143.34 Hz, with a ring of 118.05 Hz.

In contrast, yes/no questions in QA displayed rising contours, most frequently realized as L-H%, H%, and H-H%, classic markers of interrogativity in many Arabic dialects (Al Malki & Morrill, 2016; Hedberg et al., 2014). The average F0 for yes/no questions was significantly higher at 161.41 Hz, with a broader ring of 137.15 Hz, indicating a more dynamic pitch movement and enhanced intonational prominence. These tonal contours reflect a perceptual rise in

intonation, aligning with cross-linguistic findings reported in Arabic dialects such as Farasani Arabic (Abbas, 2021) and in other languages including Spanish and English (Portocarrero, 2019; Lin et al., 2013).

The presence of L-H% in QA is particularly significant. This contour indicates a gradual fall followed by a rise, which often implies speaker uncertainty or politeness—a pragmatic feature often associated with interrogativity (Pierrehumbert & Hirschberg, 1990; Alzaidi et al., 2025). Similarly, the high tone H% and the double high boundary H-H% provide strong acoustic cues to question modality. These results support the hypothesis that Qassimi Arabic utilizes rising intonational strategies to distinguish yes/no questions from declaratives.

The robustness of the declarative vs. interrogative distinction in QA was validated through statistical testing. A one-way ANOVA revealed a significant overall difference between sentence types. Complementary paired-sample t-tests also confirmed significant differences in F0 values for most sentence pairs, particularly Sentences 1, 2, and 4, thereby reinforcing the core distinction. Sentence 3 narrowly missed statistical significance, likely due to increased variability.

Such variability may stem from speaker-level inconsistencies or reading effects. For instance, unexpected tonal patterns such as H%, L-H%, H*+L%, and H-L% occasionally appeared in declarative utterances, deviating from the dominant falling contours. These anomalies were primarily observed in single repetitions and were often absent in follow-up trials, suggesting they may have resulted from slips of the tongue, prosodic reset due to emphasis, or unnatural reading strategies. Similarly, approximately 16% of yes/no questions included atypical boundary tones like H-L%, L-L%, and L%, especially among participants focused more on reading than spontaneous speech delivery. However, these variable patterns may not only be slips or reading effects, but could also reflect pragmatic nuances, such as reinforcement, emphasis, or speaker attitude, as seen in other Arabic varieties (Hamdan et al., 2025).

A noteworthy dimension of this study was the exploration of gender-based variation. Female speakers consistently produced higher F0 values across both sentence types. For declaratives, female F0 values ranged from 96.68 to 214.73 Hz, and for yes/no questions, from 100.05 to 237.20 Hz. This aligns with the biological underpinnings of vocal production, wherein females typically exhibit higher pitch due to shorter and thinner vocal folds (Lee & Martinez, 2025; Mendoza et al., 1996).

Statistical results confirmed significant differences in F0 values for three of the four sentences among female speakers. Sentence 3 did not reach significance, although visual inspection of bar graphs (see Figure 6) still revealed higher pitch levels for questions. Among male speakers, Sentences 2 and 3 reached significance, while Sentences 1 and 4 did not. Again, variability appears to have reduced statistical power rather than reversing the general pattern. Nevertheless, both male and female speakers demonstrated the same intonational directionality, underscoring the consistency of the rising pitch strategy for marking questions.

These findings are broadly consistent with prior studies on other Arabic dialects but also highlight specific features unique to QA. The use of H% and L-H% in declaratives, though infrequent, mirrors patterns found in Farasani Arabic (Abbas, 2021), suggesting that occasional high tones at sentence boundaries are not exclusive to interrogatives. Additionally, the presence of the H*+L% tone—a bitonal contour associated with contrast or stress—suggests that QA speakers sometimes encode information structure through intonation even within declarative frames.

On the interrogative side, the dominant patterns of L-H% and H-H% confirm trends seen in Urban Najdi Arabic (Al Malki & Morrill, 2016) and Lebanese Arabic (Chahal & Hellmuth, 2014), while the presence of H% as a standalone marker of rising finality is less frequently reported in prior literature. Interestingly, Salem's (2020) study on Taizzi Yemeni Arabic found a falling contour (H*L%) in yes/no questions, a finding at odds with QA data. Such contrasts reinforce the need for fine-grained, dialect-specific research and caution against overgeneralizing across Arabic varieties.

The results provide empirical support for the Autosegmental-Metrical framework in modeling QA intonation. Declaratives generally followed the L-L% and L% boundary tone configurations, while yes/no questions utilized L-H%, H%, and H-H%, reflecting the use of basic H and L tones and their combinations into phrase and boundary accents. This supports Pierrehumbert's (1980) principle of compositionality, where contours are built from independent tonal elements, and Ladd's (2008) principle of tonal sequencing.

Furthermore, the presence of high-rising patterns like H-H% in interrogatives indicates alignment between pitch accents and prosodic boundaries, which is characteristic of AM theory's approach to prominence and phrasing. The dual use of H% in both question and marked declarative forms also highlights the functional load of intonation in QA, with rising contours not only signaling modality but also discourse-level emphasis or speaker stance.

VI. Conclusion

This study examined the intonational patterns of Qassimi Arabic (QA) using the Autosegmental-Metrical (AM) framework, focusing on declarative and yes/no question forms. Declaratives predominantly end in L-L% and L%, while yes/no questions feature rising contours such as L-H%, H%, and H-H%. These distinctions were both perceptually salient and statistically significant, confirming that QA utilizes intonation systematically to mark sentence modality.

Gender-based differences were also observed, with female speakers consistently producing higher F0 values, reflecting biological vocal fold differences and supported by cross-linguistic phonetic research. Occasional tonal deviations (e.g., H-L% in interrogatives or H% in declaratives in unexpected contexts) were noted but did not undermine the overall trend.

While controlled elicitation allowed for consistency, the use of read speech may not fully capture the natural prosodic variation found in spontaneous discourse. Future research should explore broader sentence types, including wh-questions, imperatives, and focus constructions, to enrich our understanding of QA's prosodic grammar. Moreover, examining sociolinguistic dimensions such as age, education, and regional variation within Qassim would provide a fuller account of intonational diversity.

Another promising avenue lies in investigating how intonation in QA interacts with syntactic structure and pragmatic functions, such as focus and topic marking—key components of the AM model. In sum, this paper documents previously unexplored prosodic features of QA, contributes empirical data to Arabic phonological research, and supports the versatility of the AM model in accounting for tonal distinctions across Arabic varieties. It lays a critical foundation for future work in prosodic typology, variation, and theoretical modeling.

APPENDIX A. A SET OF SYMBOLS FOR THE TRANSCRIPTION OF INTONATION PHENOMENA

Tones	Transcriptions
H*	high pitch accent
L*	low pitch accent
L+H*	bitonal pitch accent with low tone followed by high tone prominence
L*+H	bitonal pitch accent with low tone prominence followed by high tone
H*+L	bitonal pitch accent with high tone prominence followed by low tone
!H*	down-stepped high pitch accent
L+!H*	bitonal pitch accent with low tone followed by a down-stepped high tone prominence
L*+H	bitonal pitch accent with low tone prominence followed by high tone
H+!H*	bitonal pitch accent with high tone followed by down-stepped high prominence
H*+!H	bitonal pitch accent with high tone prominence followed by a down-stepped high tone. L-L%: low phrase accent, low boundary tone

APPENDIX B. COMPLETE SET OF ELICITED DATA

Declarative Statements	
#	**Statement**
1	Lawn Siyyarat Ahmad aswad. Colour-PRE car- NOM Ahmad. POSS. NOM black-ADJ 'The colour of Ahmad's car is black'.
2	Al-jaw be-faransa bared. the-weather-NOM PRE -France cold- ADJ 'The weather in France is cold'.
3	Khaled mudares. Khaled- NOM teacher. M. NOM 'Khaled is a teacher'.
4	Eman ta-xsˤsˤ-t Rjadˤjat. Eman-NOM PST-Specialised-3SG. F Mathematics-NOM 'Eman specialized in Mathematics'.

Interrogatives	
#	**Statement of the intrrogative**
1	Lawn Siyyarat Ahmad aswad? Colour-PRE car- NOM Ahmad. POSS. NOM black-ADJ 'The colour of Ahmad's car is black'?.
2	Al-jaw be-faransa bared? the-weather-NOM PRE -France cold- ADJ 'The weather in France is cold'?
3	Khaled mudares? Khaled- NOM teacher. M. NOM 'Khaled is a teacher'?
4	Eman ta-xsˤsˤ-t Rjadˤjat? Eman-NOM PST-Specialised-3SG. F Mathematics-NOM 'Eman specialized in Mathematics'?

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