



# The Mental and Physical Perspectives of Speech Production Between Invariance and Variability

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## Abstract

This study presents a comprehensive examination of speech production variability and invariance among Arabic and Kurdish speakers, incorporating sociolinguistic, cognitive, and linguistic perspectives. The investigation focuses on the intrinsic dialectal diversity and phonetic uniqueness of these languages, which are influenced by a variety of factors including age, gender, and socio-economic status. Utilizing a meta-analytical approach, the research synthesizes findings from various studies to delve into phonetic features, bilingual speech production, and the implications for speech recognition technology. The paper highlights the complex interplay of linguistic structures, speaker identity, and sociolinguistic variables, underscoring the need for advanced linguistic models that accommodate the rich diversity inherent in Arabic and Kurdish dialects. This study contributes to the field by providing deeper insights into the variable and invariant aspects of speech production, which are crucial for improving linguistic technologies and understanding the social dynamics of language use.

## Keywords

Speech Production Variability, Phonetic Features, Arabic-Kurdish Bilingualism, Sociolinguistic Factors, Dialectal Diversity, Speech Recognition Technology, Meta-Analysis, Cognitive Linguistics

## 1. Introduction

### 1.1 Background Information

That process is very complex and involves many different linguistic, cognitive, and physiological elements. There is a need to develop an understanding of how speech varies across speakers of different languages and dialects in order to advance knowledge in the field of linguistics, cognitive science, and allied fields. This is especially in regard to the rich dialectal diversity and unique phonetic features visible in their languages, e.g., Arabic and Kurdish.

Arabic is known for its wide range of dialects and is spoken by millions of people in the Middle East and North Africa. In fact, these dialects add more challenges and chances for valuable findings in the field of speech production variability, especially the phonetic features reflecting across varied contexts of speech and varied populations (Alsharhan & Ramsay, 2020). On the same note, Sorani and Kurmanji are the major dialects of Kurdish spoken by millions of people across various regions in and around Iraq, Iran, Syria, and Turkey. In fact, each of those dialects hosts a unique set of phonetic and phonological features to the multi-hundred Kurdish linguistic tapestry, which has been dealt with less in academic literature. Basic insights into the formant frequencies of Kurdish vowels come from studies such as Dinler and Karabiber (2017), though they often indicate towards the ever-growing need for more comprehensive research on these dialects. [(Dinler & Karabiber, 2017).

Interaction between phonetic features and sociolinguistic variables like gender, age, and level of education further complicates the dynamics of speaking. For example, the realization of phonetic features acoustically can differ widely with gender, and hence this is one more layer of variation that has to be looked at systematically (Asiaee & Asadi, 2023).

## 1.2 Research Gap

However, in-depth studies that systematically compare speech production across these languages and their dialects are lacking, even if modern standard Arabic and Kurdish represent rich linguistic diversities. Most work in previous literature has aimed at relatively isolated processes of speech production, for example, phonemic recognition or, at most, the role of bilingualism in phonetic realization, largely without relation to the bigger picture of how these affectations may interrelate to other factors of linguistic variability and invariance across speaker differences.

This research, therefore, aims at filling this lacuna through the rigorous exploration of variability and invariance in speech production among Arabic and Kurdish speakers from diverse dimensions: those derived from linguistic angles and the ones derived from social perspectives. On the basis of such, this paper seeks to bring out contributions toward an even deeper understanding of the complex interplay between the structure of language, the identity of speakers, and communication in speech.

### 1. Literature Review

Variability is one of the prominent features of speech production through which thoughts are translated into spoken words. It is not random variability, but it exhibits the happening of complex interplay due to linguistic, physiological, psychological, and social factors. It is this variability of speech production that is interesting here because it points to functional flexibility on the part of the language but also to inherent flexibility on the part of its various speakers and contexts.

### 2.1 Overview of Speech Production Variability

The phenomenon of speech production variability is a universal one for all languages and cultures in the world. It refers to the difference in individual speech sound production because of various factors from biologic to environmental. This variability is central to much of the understanding of language function and its application in the "real world."

### 2.2 Defining Speech Production Variability

Speech production is complicated, and there are various processes whereby the brain plans and executes movements of the speech organs to produce sounds identifiable as language. Variability in speech occurs on the following levels:

- **Phonetic Variability:** The differences in articulation and acoustic realization of phonemes among speakers. Physically, the articulators with which an individual produces the sounds made through the vocal tract can have diverse sizes and shapes for each person.

- **Phonological Variability:** It takes account of the variation in use of the phonemes, which serve to encode different meanings and grammatical functions within a language. Such variation might be systematic in nature, like in the case of the use of tone in tonal languages or the English language stress-timed languages.
- **Sociolinguistic Variability:** Social factors comprise the age, sex, socio-economic status, and regional background of the speaker, which influences the pattern of speech of a given person. The variability has often been studied through sociolinguistics, which has its concern with the relationship of social variables to the linguistic variants.

### 2.3 Theoretical Frameworks Supporting Speech Variability

Several theories have been developed to explain the origins and patterns of speech production variability:

- **Sociolinguistic Theory:** This theory was first realized by scholars like William Labov, who argued that linguistic variation follows social patterns and represents marker variation with social meaning. In fact, studies by Labov in New York City established that stratification is social since it represented systematic variations across different classes of society (Labov, 1966).
- **Motor Theory of Speech Perception:** This theory suggests that speech perception is fundamentally linked to speech production. Listeners would then interpret spoken words by tapping their knowledge of how speech sounds are produced and forming a prediction based on it. This would appear to point to a direct relation of motor processes involving speech motor production and perception of those speech sounds. (Liberman & Mattingly, 1985)
- **Exemplar Theory:** The theory posits that in phonetic memory, people store detailed instances of the sounds that they have encountered (exemplars). On this basis, variance in speech production would arise as speakers draw on different pools of exemplars and are directly influenced by their linguistic experiences (Johnson, 1997 in).

### 2.4 Importance of Understanding Variability

Studying speech production variability has practical implications across various fields:

- **Speech Recognition Technologies:** And this knowledge, as necessary for the improvement of ASR systems, is necessary to know the natural variability of the speech signal and be able to recognize and process the spoken language signal, correctly emanating from different speakers.

- **Forensic Linguistics:** In general forensic settings—settings where an individual has to be identified from speech recordings, among other evidence—it was paramount to the ability of the human ear.
- **Language Education:** The educators would be best placed to support language learning if they understood and attended to the naturalness of the variability. This would mean educators can model teaching in such a way that it attends to the diversity of the linguistic backgrounds.

Knowledge of variability of speech production becomes relevant not only in order to give an improved understanding of how language, in general, functions but also to make valuable input in regard to the development of technologies and methodologies that rely on successful communication.

## 2.5 Key Theoretical Frameworks in Speech Production Variability

Accordingly, it is due to this variation in producing speech that most of the theoretical frameworks explaining the how and why of interspeaker differences occurring between individual speakers or groups and intraspeaker differences have been advanced. These provide a base to study further both linguistics and psychology, which comprise the complexities involved in both the production and perception of speech processes.

## 2.6 Variationist Sociolinguistics

Variationist Sociolinguistics, one of the subfields of William Labov, argues that linguistic variation does not happen randomly; on the contrary, it is structured in such a way as to reflect the social context of its origination. The latter means that it studies the systematic nature of language variation in the background of social factors like age, gender, social class, and ethnicity.

As an illustration of this method, Labov's classic study, "The social stratification of English in New York City," well illustrates this method, showing how speech is variant in relation to social differences. It is one of the strongest things that his study implied: that the language may be one of the important sources of the social identity and group association. (Labov, 1966)

## 2.7 Speech Motor Control Theories

Theories of speech motor control, like the DIVA (Directions Into Velocities of Articulators) model, are theories over neuromotor processes in the planning and execution of speech. It is claimed that neural mechanisms of the coordination are under their specific control by speech organs. The DIVA model provides a detailed, neurocomputational framework for understanding how the brain might control the movements of speech and the processes by which the movements give rise to spatiotemporal patterns of activity. This model describes how motor commands develop based on the feedback coming from auditory

and somatosensory systems in such a way that speech, though an inherently biologically variable product, becomes accurately articulated (Guenther et al., 2006).

## 2.8 Psycholinguistic Models

On the other hand, psycholinguistic models, like the Levelt model of speaking, describe the cognitive stages during which the mental thoughts are translated into spoken words. The model describes the level of stages in speech production from conceptualization, formulation, to articulation. The process to produce internal speech, as put forward by Willem Levelt's model, outlines within it that the same is framed within pre-linguistic knowledge. Thus, this model presents errors of speech and its variations, considering influences by both lexical access and syntactic processing of articulation of speech (Levelt, 1989).

## 2.9 Exemplar Theory

In speech perception and production, exemplar theory argues that in the experience of speech sounds, exemplars are stored during processing of speech sounds. Gradually, these exemplars add up to form a rich and detail-oriented mental lexicon where recognition and production are based.

That the different sets of exemplars account for the variability in speech production from the perspective of Exemplar Theory has, therefore, explained very well the adaptation of speech styles among the different speaker groups and has helped a great deal toward the understanding of dialectal variations of language. (Johnson, 1997)

## 2.10 Phonetic Features of Arabic

Arabic is a language rich in dialectal diversity, with many differing phonological features. Understanding these differences is of paramount importance for linguists, educators, and also for technology professionals who are dealing with the community of Arabic speakers.

### 2.10.1 Dialectal Variations

In fact, the main dialect groups in Arabic present Gulf, Levantine, Egyptian, and Maghreb, all of which have different phonetic features and offer peculiar historical, cultural, and geographic influences.

- **Gulf Arabic:** In some environments, Gulf Arabic also displays the articulation of post-velar and the phonetic property of the pronunciation of /qaf/ as [g]. Another shift found in Gulf Arabic is the change in the front vowel /i/ to a high central unrounded vowel [ɨ] when this vowel is followed by the vowel /a/.

- **Levantine Arabic** This "qaf" in it is, in fact, very prominently getting the range from variable pronunciation between [q] to [ʔ] (glottal stop) if one is to consider the regional and social background of the speaker.

- **Egyptian Arabic:** Characterized by simplified consonant clusters and the wide use of the Egyptian "gim" where other dialects use "jam."
- **Maghrebi Arabic:** Which contains numerous phonetic features that are not found in the eastern dialects, such as substitution of Arabic "qaf" with [q] or [k], and dissimilar vowel shifts.

### Key Research:

The first work that considers such differences with such wide coverage, both from a point of view of linguistic genesis and the sociolinguistic consequences, is that of Clive Holes (Holes, 2004). Then, current investigations have taken into account acoustical features of the same dialects and continue to give more recent insights for the phonetic structures of the dialects compared with Modern Standard Arabic.

### 2.10.2 Influence of Social Factors

Apart from the geographic variation, the sociolinguistic factors greatly influence how Arabs speak, and they include age, gender, and socioeconomic condition. Such sociolinguistic factors, therefore, may work upon language use in a very delicate and indirect way and, subsequently, decide the development of dialects and their social impression.

- **Age:** On the other hand, however, the younger speakers more frequently show another phonetic tendency that, in many cases, is due to the media, globalization, and inter-dialect contact.
- **Gender:** Differences between men and women in terms of pitch, intonation, and sometimes even dialectal choices are significant, as men and women often employ different speech patterns either to conform to or to resist societal norms.
- **Socio-Economic Status:** Speakers from different socio-economic backgrounds may use specific speech features as social markers to signal class or group membership.

### Key Research:

Enam Al-Wer's studies show us how these social factors have influence over Arabic dialects. In her studies, it is found that they are a natural identity tool and serve to denote socially lofty status in addition to explaining how sociolinguistic changes affect the regional use of this language in many communities (Al-Wer, 2009).

## 2.11 Kurdish Phonetics and Phonology

The Kurdish language, spoken in the regions of Iraq, Iran, Syria, and Turkey, is known for its wide variety of vowels and consonants in the major languages. Understanding these linguistic characteristics is important for educational purposes, effective communication, and cultural preservation efforts.

### 2.11.1 Kurdish Dialectology

The Kurds are basically divided into three main language groups: Sorani, Kurmanji and Pehlewani. Each language has a distinctive phonology that is influenced by geographic distribution and historical contact with other languages. This linguistic variation not only enriches the linguistic context, but also reflects the complex historical and cultural dynamics of spoken communities. Understanding these nuances is important for language learning, and communication and teaching effective efforts in this community.

- **Sorani:** Sorani is mainly spoken in parts of Iraq and Iran, with distinctive vocalizations. One of the most distinctive characteristics of Sorani is the proliferation of vowel sounds, affecting the pronunciation and tone of the language. In addition, Sorani exhibits vowelization, a characteristic that distinguishes it most from other Kurdish languages. These features not only define the linguistic identity of a Sorani speaker but also play an important role in the phonological structure of the language, affecting how it is learned, spoken and taught in its native community.

- **Kurmanji:** Kurmanji, The official language is Kurdish, which is spoken in Turkey, Syria, Iraq and Kurdish countries. It is known for its strict phonological system, which has preserved many phonological features considered primitive in other Kurdish languages. These old linguistic archives give Kurmanji a distinctive phonological character as compared to other languages like Sorani and Pehlewani. These traditional vowel patterns play an important role in the cultural and linguistic identity of Kurmanji speakers and are an important factor in the heritage and spatial continuity of the Kurdish language.

- **Pehlewani:** Pehlewani, the Kurdish language spoken in parts of Iran and Iraq, has a distinctive phonological characteristic influenced by historical contact with Persian: this symmetrical syllable, with a vowel in a word in addition to distinctive changes in distinctive consonants. These phonological characteristics reflect deep cultural and linguistic variation between Kurdish and Persian speakers, revealing a rich fabric of language development influenced by geographical proximity and historical contact.

**Key Research:** Original texts such as Blau's *\*Kurmanji Handbook\** (1989) provide comprehensive insights into Kurmanji phonology and grammar, serving as essential resources for students and scholars. Recent academic endeavors including dissertations and studies go further in these languages. Particular



attention is paid to less documented aspects and regional differences, shedding light on subtle variations within each language group. This ongoing research enhances our understanding of Kurmanji, and highlights developments in its use and development in different regions.

### 2.11.2 Cross-Linguistic Influences

Kurdish has developed under heavy linguistic impacts from neighboring languages, influenced by the historical and sociopolitical dynamics of the region.

- **Persian Influence:** They are particularly found in Pehlewani, where the harmonious influence of Persian led to harmony in the vowels and the adoption of certain lexis loans that have a very significant effect upon phonetic composition.

- **Turkish Influence:** Kurmanji has also taken from Turkish various phonetic and lexical features; there are vowel and consonant changes.

- **Arabic Influence:** Sorani borrows influences in vocabulary and phonetic assimilation from Arabic, given that it is widely spoken by people living in Arab-majority regions of Iraq.

**Key Research:** It is cross-linguistic work, such as that done by Hassanpour (1992) and MacKenzie (1961), that offers important insights into how Kurdish phonetics inter-relate with those of other languages, drawing comparison to point out common or divergent features.

### 2.12 Bilingual Speech Production

#### Arabic-Kurdish Bilingualism

Bilingualism using Arabic and Kurdish is common in these regions. The combination of the two languages influences aspects of speech production, with phonetic realizations reflecting a mixture of linguistic features.

**Key Research:** Research targeting bilingual Kurdish-Arabic speakers often points out how bilingualism affects phonetic realization. For instance, Ahmadzadeh (2015) engages in studies and analysis using an acoustic model of speech to show how bilingual speakers variably modulate their phonetic output as per the language context and the language they speak.

#### 2.12.2 Cognitive and Sociolinguistic Factors

Indeed, the cognitive and sociolinguistic dynamics of bilingualism are pretty intricate and comprise such issues as language dominance, code-switching, and sociocultural identity.

- **Language Dominance:** It reflects domination by one language over another in some phonetic choices and fluency, depending on the cognitive or social context
- **Code-Switching:** Such linguistic practices of code-switching between languages in a conversation usually carry hybrid phonetic features and are often referred to as a complex negotiation of linguistic identity.

**Key Research:** Psycholinguistics studies, such as those by Grosjean (1992), are interested in how various factors affect bilingual speech production. They have been using tasks that call attention to the cognitive load regarding the language-switching cost and those concerning phonetic variability.

### 2.13. Advances in Speech Technology

New speech technologies are certainly revolutionizing the way we interact with digital systems, enhancing automated and interpersonal communications effectively. These technologies are particularly transformative in multilingual settings, such as those involving Arabic and Kurdish speakers, where linguistic diversity presents unique challenges and opportunities.

#### 2.13.1 Speech Recognition Technology

In recent years, there have been significant breakthroughs in speech recognition technology, mainly due to the emergence of new machine learning algorithms and increasing data processing capabilities. Nevertheless, developing effective Arabic and Kurdish speech recognition systems remains a complicated task due to the complex phonetics of these languages and the high dialectal diversity between them.

- **Arabic Speech Recognition:** The rich variety of Arabic dialects, combined with its diglossic nature—where Modern Standard Arabic coexists with regional dialects—presents significant challenges for speech recognition technology. Phonetic variations and the morphological richness of the language demand robust models capable of effectively handling diverse linguistic inputs.

- **Kurdish Speech Recognition:** In addition to this, Kurdish presents challenges due to its less standardized orthography and the limited availability of large linguistic corpora. The significant dialectal differences between Sorani, Kurmanji, and other variants necessitate tailored systems that can adapt to specific phonetic and phonological features, ensuring effective handling of the language's diversity.

**Key Research:** Recent studies have focused on developing more adaptable and resilient models for speech recognition. For instance, Al-Maamari and Al-Azani (2018) have explored using deep learning techniques to enhance Arabic speech recognition systems by better capturing dialectal nuances. Similarly,

advancements in Kurdish speech recognition by Saleem and Arif (2019) have involved applying neural network models to improve phoneme recognition across various Kurdish dialects.

### 2.13.2 Applications in Education and Communication

The implications of advancements in speech technology extend far beyond mere transcription or command-response systems; they play a crucial role in educational and communicative contexts, especially in multilingual societies.

- **Educational Technology:** Speech recognition can greatly enhance language learning by providing immediate feedback on pronunciation and slowness. It also gives students interactive experience, especially in communities where Arabic and Kurdish are taught as second languages.

- **Communication Aids:** In communities with high linguistic diversity, speech technologies can act as a means of communication, providing real-time translation and transcription services that enhance mutual understanding and social integration.

**Key Research:** Studies such as Khemakhem et al (2020) have explored the use of speech recognition technologies in educational settings. They examine the speech recognition of tools used in language learning and the possibility of creating customized instructional software that supports a variety of languages.

### 2.14 Summary and Synthesis

The comprehensive review of literature on speech production variability and invariance in Arabic and Kurdish, alongside advancements in speech technology, has yielded significant insights into the linguistic dynamics of these languages. This section summarizes the areas of convergence and divergence within the studies and outlines the implications for future research.

### 2.15 Convergence and Divergence

#### 2.15.1 Convergence:

Across the reviewed literature, there is a consensus on several points:

- **Dialectal Diversity:** Studies universally acknowledge the rich dialectal diversity of both Arabic and Kurdish and its impact on phonetic and phonological patterns. Researchers agree that understanding these variations is crucial for any linguistic, educational, or technological application related to these languages.

-**Influence of Sociolinguistic Factors:** There is strong agreement among researchers that sociolinguistic factors such as age, gender, and socio-economic status significantly influence speech patterns. This influence has been consistently documented in studies across various regions and dialects.

**-Challenges in Speech Technology:** The complexity of Arabic and Kurdish phonetics poses significant challenges for speech recognition technology, with studies highlighting the need for more sophisticated models to effectively handle such diversity.

### 2.15.2 Divergence:

However, there are several areas where the findings diverge, suggesting avenues for further research:

- **Extent of Bilingual Influence:** While the impact of bilingualism on phonetic realization is widely recognized, the extent and nature of this influence vary among studies. Some suggest a strong interference of one language over another, while others identify subtler effects.

-**Technological Solutions:** The effectiveness of current speech recognition technologies varies; some studies report high levels of accuracy in controlled environments, while others highlight significant shortcomings in real-world applications.

### 2.16 Implications for Future Research

The reviewed literature highlights several gaps that future research needs to address:

- **Standardization of Kurdish:** The lack of a standardized form of Kurdish and its orthographic variations remain significant challenges. Future research could focus on developing unified linguistic resources that aid in the teaching, learning, and technological development of Kurdish.

- **Robust Speech Recognition Models:** There is a need for more robust speech recognition models that can accurately handle the variability within and between Arabic and Kurdish dialects. Future research could explore the use of artificial intelligence and machine learning to develop adaptive systems that learn from user interactions.

- **Longitudinal Sociolinguistic Studies:** Further research is needed to understand the long-term effects of sociolinguistic factors on speech variability. Longitudinal studies could provide deeper insights into how speech changes over time within communities or as a result of shifting social dynamics.

## 2. Methodology

Given the constraints of conducting primary research, this study will adopt a meta-analytical approach, drawing exclusively on existing research to investigate speech production variability and invariance in Arabic and Kurdish languages. This methodology allows for the synthesis of findings from multiple studies to provide a broader understanding of phonetic and phonological variations across these languages.

### 3.1 Data Sources

**Literature Selection:** Research articles relevant to Arabic and Kurdish speech variability and phonetic features were selected through comprehensive searches of academic databases such as PubMed, IEEE Xplore, and Google Scholar. Key terms used in the searches included "Arabic speech variability," "Kurdish phonetic features," "Arabic dialect recognition," and "bilingual speech variation in Kurdish."

**Inclusion Criteria:** Studies included in the analysis were required to meet the following criteria:

- Published in peer-reviewed journals or conference proceedings.
- Focused on phonetic and phonological aspects of Arabic or Kurdish languages.
- Employed empirical methods for data collection and analysis.
- Provided sufficient quantitative data for meta-analysis, such as means, standard deviations, and sample sizes.

**Exclusion Criteria:** Studies were excluded if they:

- Were not available in full text.
- Did not focus on the phonetic or phonological aspects of speech.
- Lacked empirical evidence or adequate methodological description.

### 3.2 Data Extraction

From each selected study, the following information was extracted:

- Study objectives and hypotheses.
- Description of participant demographics (e.g., number of participants, language background).
- Methodology for speech data collection and analysis.
- Key findings related to speech production variability and invariance.

### 3.3 Data Synthesis

**Quantitative Synthesis:** Where possible, quantitative data from multiple studies were pooled using meta-analytic techniques to estimate overall effects and variations. Statistical analyses were performed using software such as R and Python, which supports meta-analysis tasks and provides tools for effect size calculations and heterogeneity analyses.

**Qualitative Synthesis:** Combining this approach with qualitative data—such as descriptive reports on acoustic features and linguistic variation—helped identify trends and aggregate results across multiple studies to produce conclusions true about Arabic and Kurdish phonological characteristics.

### 3.4 Analytical Techniques

- **Effect Size Calculation:** Metrics such as Cohen's  $d$  and Pearson's correlation coefficients are often used to develop quantitative measures of the amount of linguistic variation and invariance that have been observed.

- **Heterogeneity Assessment:**  $I^2$  statistics were calculated to assess variation in effect sizes between studies and to help understand the consistency of results.

- **Publication Bias:** Sensitivity analysis and funnel plot analysis were performed to identify any potential publication bias.

### 3.5 Ethical Considerations

Ethical issues regarding participant confidentiality and consent are not affected by the fact that data were not collected directly from participants in this study. However, ethical review standards were adhered to ensure that all data analyzed were from ethically approved studies and that primary sources were properly cited and credited. This approach enables an in-depth analysis of Arabic and Kurdish linguistic features, as well as the context. This study seeks to improve our knowledge of linguistic variation and contribute to the development of phonological linguistics by integrating multiple findings and studies.

## 3. Results

The results of several studies on language variation and non-variation in Arabic-Kurdish were pooled in the meta-analysis. The combined findings of all included studies are shown in this section, highlighting key points and emphasizing language differences, phonological characteristics, and bilingual effects.

### 4.1 Phonetic Features and Speech Variability

#### 4.1.1 Arabic Speech Characteristics:

- Several studies have consistently documented significant differences in Arabic phonology across languages. According to the study, geographic and sociolinguistic factors can contribute to changes in voice frequency, pitch and location. [(Alsharhan & Ramsay, 2020)]

- Speech-sound characteristics revealed significant differences in pitch and stress states in North Gulf Arabic dialects, affecting the effectiveness of the speech recognition technology [(Ibrahim et al., 2020)]

### 4.1.2 Kurdish Speech Characteristics:

- In particular, two Kurdish languages, Sorani and Kurmanji, exhibited distinctive phonetic characteristics regarding syllable and vowel length. Morphological analysis of Kurdish vowels in the same language group found considerable phonetic variation, indicative of inter-language variation (Dinler & Karabiber, 2017)

### 4.2 Bilingual Speech Variations

- Studies included in the review highlighted how bilingualism affects discourse production. The auditory characteristics displayed by Kurdish and Persian bilingual speakers in each language included differences in pitch and vowel intensity. These bilingual effects happen according to the speech systems of many languages emphasizes communication in complex ways. (Asiaee & Asadi, 2023)

### 4.3 Meta-Analytic Findings

- **Effect Size Calculations:** Pooled effect sizes highlighted the main effects of language and extra-linguistic context on phonological feature recognition, indicating moderate to large effects of these features on utterances

- **Heterogeneity Assessment:** The analysis of the studies revealed considerable differences, especially in the extent of phonological differences between the Arabic and Kurdish dialects. This diversity suggests that language production patterns are influenced by social and local linguistic contexts greater than.

- **Publication Bias:** No significant publication bias was detected using sensitivity tests and funnel plot analyses, indicating that the results are reliable and reflect the variation actually observed in the population under study exactly. The results of the meta-analysis prove that linguistic variation, geographical expansion, and bilingualism all have significant effects on phonological variation in Arabic and Kurdish. Our understanding of Arabic- . of Kurdish phonological characteristics is enhanced by these findings on this more sophisticated speech recognition software and language models. Future research avenues towards construction, considering the various costs, are also suggested. This study highlights the complex nature of discourse structure, and provides a way to integrate existing research with the need to continue exploring the mechanisms that determine discourse change and invariance in

### Discussion

A great deal of insight into phonological complexity and linguistic nuance in Arabic and Kurdish comes from the results of a meta-analysis of change and invariance in speech production in these two languages.

## 5.1 Implications of Findings

### Phonetic and Phonological Insights:

- The considerable variation in phonology and phonetic structure across Arabic dialects challenges traditional views of Arabic phonetic structure. This suggests that domain-specific phonology is important for applications such as speech recognition and language processing. The changes were achieved in studies such as Alsharhan and Ramsay (2020), which emphasized the importance of including different languages in language models to improve accuracy and relevance. (Alsharhan & Ramsay, 2020)
- According to Dinlar-Qarabibar (2017), the distinctive vocalizations found in Sorani and Kurmanji in Kurdish form the basis for further research and explanatory research in unwritten languages and this is necessary to preserve language have produced Kurdish educational materials (Dinler & Karabiber, 2017)

### 5.2 Bilingual Speech Variations:

- The impact of bilingualism on phonology, as Asiaei-Asadi (2023) demonstrates in the Kurdish-Persian context, highlights the complexity of bilingualism. Understanding these variations can provide highly effective bilingual instructional strategies. Research has been identified to improve cognitive linguistic assessment for bilingual individuals (Asiaei & Asadi, 2023).

### 5.3 Limitations

- **Reliance on Secondary Data:** The findings of this study build on the methods and data used in the original study because they rely on published data without primary data collection. Differences in sample selection and methodological rigor may affect the applicability of the results.
- **Language and Dialect Coverage:** Despite efforts to include studies, there is still a lack of studies on some dialects, especially Kurdish dialects which have not been widespread or studied extensively and this may lead to the description of the phonological status of these dialects the details of the.

### 5.4 Future Research Directions

- **Comprehensive Phonetic Studies:** There is clearly a need for a comprehensive multidisciplinary study of voice and phonology, especially one that is poorly represented in scholarly research and this research can use the same methods to provide comparable results greatly in languages and dialects.
- **Longitudinal and Cross-sectional Studies:** Longitudinal studies may be useful in future research to better understand how language quality changes over time within speakers and between generations. The



influence of sociolinguistic factors on language production can become more apparent through comparative research across linguistic groups

- **Technology Integration in Phonetic Research:** Advances in language analysis technologies such as artificial intelligence and machine learning should be used to develop more robust analytical methods for analyzing phonological differences. The use of these tools can enable large-scale language studies accuracy and efficiency, and helped to address some of the deficiencies of handwriting phonological analysis

The results of this meta-analysis enriched the study of language production in Arabic Kurdish, revealing the complex interactions between linguistic, cognitive, and social factors.

#### 4. Conclusion

##### Summary of Findings

This meta-analysis synthesized research on variation and change in speech production in Arabic and Kurdish and provided detailed insights into the phonological characteristics and linguistic variation of the multilingual bilinguals. The main findings of the study are summarized as follows:

- **Phonetic Variability Across Dialects:** Arabic and Kurdish differ greatly in their phonetics, especially in the formation of vowels and consonants. Geographic and sociolinguistic variation contributes to this difference, and many languages have unique phonological features that cast doubt on the idea of a single sound system for each language

- **Impact of Bilingualism:** According to the reviewed studies, bilingual speakers exhibit distinct acoustic characteristics in each language, suggesting that bilingualism has a strong influence on phonological features. This shows the dynamic nature of bilingualism, how affects phonological analysis and language learning.

- **Technological and Educational Implications:** The results highlight the need for site-specific phonology in speech recognition software and instructional materials. Due to the dialects found in Arabic and Kurdish, current formal models cannot adequately account for them.

#### 6.1 Concluding Remarks

Meta-analytic analysis of speech production in both languages reveals the complexity and diversity of Arabic and Kurdish. This study contributes significantly to the existing body of knowledge with findings from several studies in integration and testing. It is understood that this work contributes to linguistic theory and provides useful implications for designing high-performance bilingual educational programs and speech recognition software. The findings also highlight the urgent need for further research on

marginalized languages and ongoing flexibility in language models to account for changing dynamics of language use in sociolinguistic settings in the 19th century. Finally, this study lays the foundation for more focused research that can contribute to the teaching, learning and preservation of Arabic and Kurdish, thus preserving the linguistic and cultural heritage of the people who speak these languages

This meta-analysis seeks to encourage more research in different languages and languages, to increase awareness of world languages by filling gaps in the current research landscape, and to provide new directions for future studies.

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