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Phonological Variation and Accent Perception among Bilingual Speakers

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ABSTRACT: This mixed-methods experimental sociophonetic study examines phonological variation and accent perception among bilingual speakers by linking acoustic production, listener evaluation, and speaker interpretation. The study analyzed 72 bilingual adults from university and community settings and 90 independent listeners recruited between 18 January and 30 April 2021. We collected speech data through word-list production, a controlled reading passage, picture description, and semi-structured conversational speech, yielding 8,640 target tokens after excluding clipped, overlapped, or noisy items. Acoustic analysis measured vowel centralization, stop-consonant voice onset time, stress ratio, speech rate, and intonation range. Listeners rated accent strength, intelligibility, comprehensibility, native-likeness, competence, warmth, and social belonging on 9-point scales. Mixed-effects models showed that late-dominant bilinguals produced greater vowel centralization than early-dominant bilinguals (beta = 0.42 Bark, 95% CI [0.24, 0.60], $p < .001$) and higher VOT variability (beta = 8.70 ms, 95% CI [4.60, 12.80], $p < .001$). Listener ratings showed that accent strength predicted lower native-likeness (beta = -0.74, $p < .001$) more strongly than intelligibility (beta = -0.18, $p = .041$), while bilingual listener experience moderated competence judgments. Interview themes indicated that listeners interpreted accent as identity, belonging, vulnerability, pride, and strategic accommodation. The study presents an integrated sociophonetic interpretation framework linking acoustic form, listener perception, social evaluation, and identity positioning.

Keywords: phonological variation; accent perception; bilingual speakers; sociophonetics; language attitudes.

I. INTRODUCTION

Bilingual speakers rarely produce or perceive speech in ways that one language system alone can explain. Their pronunciation may reflect long-term contact between phonological categories, differences in language dominance, age of acquisition, daily exposure, and the social meanings attached to accent. In multilingual communities, accent is both a linguistic pattern and a socially evaluated sign. It may index education, migration history, community belonging, institutional legitimacy, professional credibility, or perceived foreignness. This study addresses a specific gap: bilingual accent is often measured acoustically or judged perceptually, but few studies connect acoustic form, listener evaluation, and bilingual speaker experience in a single integrated design.

Sociolinguistic research has long shown that phonetic variation carries social meaning. Labov's foundational account of sound change and social evaluation established the historical basis for treating pronunciation variation as socially patterned [1]. Contemporary sociophonetic scholarship integrates acoustic analysis with regional, social, stylistic, and identity-based interpretation [2]. Experimental work further shows that phonetic imitation is socially selective rather than purely mechanical [3]. Perceptual

adaptation studies likewise show that listener experience shapes how listeners process unfamiliar accents [4].

The need for an integrated production-perception-identity design is especially strong in bilingualism research. A bilingual speaker may show measurable variation in vowel quality, consonant timing, stress placement, or intonation range, yet listeners may interpret those features through social expectations rather than acoustic evidence alone. Listener judgments of accent strength, native-likeness, or competence may therefore exceed the speech signal's actual effect on intelligibility. This distinction is not a minor methodological issue: it determines whether bilingual pronunciation is interpreted as communicative variation, social evaluation, or an unjustified marker of speaker limitation.

Contemporary models of second-language speech emphasize that age of acquisition, input, language use, and the interaction of L1 and L2 phonetic categories jointly shape accent development [5]. Meta-analytic evidence shows that comprehensibility and native-likeness are distinct outcomes influenced by phonological and rater factors [6]. Longitudinal research further indicates that motivation and learning experience can contribute to changes in comprehensibility and accentedness over time [7]. These findings show that accent is not simply a marker of ability; it reflects complex bilingual learning histories and language-use conditions.

However, acoustic differences alone do not determine communicative consequences. An accented voice may remain fully intelligible while still being judged as less native-like, less institutionally appropriate, or less professionally authoritative. Conversely, a familiar accent may be judged positively even when it differs from standardized pronunciation. The distinction between accentedness, comprehensibility, and intelligibility is therefore central to the present study. Bilingual speakers often report being understood linguistically but evaluated socially, and this tension between acoustic variation and social judgment is the main problem this study addresses.

The originality of the present study lies in linking four layers that are often examined separately: acoustic phonological variation, listener perception, bilingual speaker experience, and social identity. Controlled recordings and acoustic analysis document production patterns; a listener-rating experiment tests how listeners perceive selected speech samples; and interviews examine how bilingual speakers interpret accent as part of identity, belonging, vulnerability, and accommodation. This combination strengthens the study's evidential basis by avoiding reducing accent to phonetic measurement alone or to subjective attitude alone.

The study is situated within sociophonetics, bilingual phonology, language attitudes, and social identity research. It focuses on bilingual adults who use two languages regularly across educational, community, professional, and intercultural settings. The analysis treats accent as a patterned outcome of language experience and a social object of evaluation.

II. RESEARCH PROBLEM

This study addresses the production-perception-identity evidence gap in bilingual accent research. Bilingual speakers may produce systematic pronunciation patterns shaped by cross-linguistic influence, language dominance, age of acquisition, and frequency of use. At the same time, listeners may interpret those patterns through assumptions about proficiency, intelligence, education, authenticity, or belonging. The problem is not simply that bilingual speakers have accents; it is that accents are often evaluated as social evidence, sometimes in ways that exceed their actual effect on intelligibility.

Acoustic analysis alone cannot explain this problem because it identifies phonetic differences without showing how listeners perceive or socially evaluate them. Listener-rating studies alone are also insufficient because they may reveal attitudes without documenting the speech features that shaped those judgments. Interview-only studies are limited in another way because they explain lived experience without connecting it to acoustic or perceptual evidence. A strong sociophonetic design therefore requires evidence from speech production, acoustic measurement, listener evaluation, and speaker reflection. This study frames bilingual accent as an interaction among acoustic features, listener judgments, and bilingual speakers' experiences.

III. RESEARCH OBJECTIVES, QUESTIONS, AND ANALYTICAL EXPECTATIONS

1. RESEARCH OBJECTIVES

- To identify recurring segmental and suprasegmental patterns of phonological variation in bilingual speech production.
- To test whether language dominance, age of acquisition, exposure, and frequency of use predict acoustic phonetic measures.
- To estimate how independent listeners evaluate bilingual accents in relation to accent strength, intelligibility, comprehensibility, native-likeness, competence, warmth, and social belonging.
- To interpret how bilingual speakers understand accent as a marker of identity, authenticity, stigma, belonging, and accommodation.
- To clarify implications for pronunciation teaching, intercultural communication, language assessment, and inclusive multilingual policy.

2. RESEARCH QUESTIONS

- RQ1: Which segmental and suprasegmental phonological variation patterns are most visible in the recorded speech of bilingual speakers?
- RQ2: To what extent do language dominance, age of acquisition, exposure, frequency of use, and task type predict acoustic measures of bilingual accent variation?
- RQ3: To what extent do acoustic predictors, speaker profile, and listener background predict listener ratings of accent strength, intelligibility, comprehensibility, native-likeness, competence, warmth, and social belonging?
- RQ4: How do bilingual speakers interpret their own accents in relation to identity, authenticity, stigma, belonging, and accommodation?
- RQ5: What implications do phonological variation and accent perception have for pronunciation teaching, intercultural communication, language assessment, and inclusive multilingual policy?

3. QUANTITATIVE HYPOTHESES

- H1: Later age of acquisition and lower current exposure will predict greater vowel centralization and higher stop-consonant VOT variability.
- H2: Task type will significantly affect acoustic outcomes, with reading and word-list tasks showing more monitored speech than conversational speech.
- H3: Accent strength will predict native-likeness more strongly than intelligibility, indicating that accentedness and actual understanding are distinct perceptual dimensions.
- H4: Listener bilingual experience will moderate social-evaluative ratings, with bilingual-experienced listeners showing weaker negative associations between accentedness and competence.

4. QUALITATIVE ANALYTICAL EXPECTATION

Interview analysis is expected to show that bilingual speakers interpret accent evaluation through identity, social belonging, stigma, and accommodation rather than pronunciation accuracy alone.

IV. LITERATURE REVIEW

1. SOCIOPHONETICS, ACOUSTIC VARIATION, AND BILINGUAL SPEECH

Sociophonetics provides the central basis for this study because it examines how fine phonetic detail participates in social meaning. Variationist sociolinguistics established that pronunciation differences are systematic and socially meaningful [1]. More recent sociophonetic work links acoustic detail to social identity, style, and perception [2], [3]. Listener adaptation to unfamiliar accents further shows that perception is experience-sensitive [4]. In bilingual contexts, this approach matters because accent is not just a bundle of segmental substitutions or prosodic differences. It is a speech style produced within histories of language contact and evaluated within specific social settings.

Cross-linguistic influence often shapes bilingual phonological variation. The revised Speech Learning Model emphasizes dynamic interaction between L1 and L2 phonetic categories, shaped by input and experience [5]. Meta-analytic evidence also indicates that listener judgments of comprehensibility and native-likeness depend on multiple phonological and rater factors [6]. Longitudinal evidence shows that motivation can covary with pronunciation development [7]. Research on dominance switching shows that production and perception can shift with bilingual language dominance [8].

The literature on ultimate attainment and bilingual speech learning confirms that accent is not simply a sign of low proficiency. Recent reviews show that pronunciation attainment depends on instruction, experience, and the construct being measured [9]. The Perceptual Assimilation Model remains a foundational account of how non-native sounds are mapped onto existing perceptual categories [10]. Experimental work with early and late bilinguals shows that language mode can shift perceptual categorization boundaries [11].

2. *LANGUAGE DOMINANCE, AGE OF ACQUISITION, EXPOSURE, AND PHONETIC DRIFT*

Language dominance and age of acquisition are central to bilingual phonology, but they do not operate independently. A bilingual speaker's dominant language may shift as education, work, family life, and community participation change. Chang's work on rapid phonetic drift demonstrates that even short-term second-language exposure can influence first-language speech production [12]. Experimental evidence on short-term phonetic training further shows mutual influence between native and non-native vowel systems [13]. These findings suggest that bilingual phonology is adaptive rather than static.

Studies of bilingual phonetic interaction show that cross-language influence can appear in vowel quality, stop timing, rhythm, stress, and intonation. Simonet documented phonetic consequences of dynamic cross-linguistic interference among proficient bilinguals [14]. Baker and Trofimovich showed that bilingual phonetic systems may interact in ways that affect vowel production and category organization [15]. More recent task-based research demonstrates that segmental, prosodic, and temporal features contribute differently to accentedness and comprehensibility across speaking tasks [16]. This body of research justifies the present study's inclusion of both segmental and suprasegmental measures rather than a narrow focus on isolated vowels or consonants.

3. *ACCENT PERCEPTION, INTELLIGIBILITY, COMPREHENSIBILITY, AND LISTENER ADAPTATION*

Accent perception research has distinguished between accentedness, comprehensibility, and intelligibility. Munro and Derwing's foundational work showed that speech can be strongly accented while remaining comprehensible or intelligible [17]. More recent research shows that learners' backgrounds affect listeners' judgments of comprehensibility [18]. Cross-variety research likewise shows that accentedness and comprehensibility can diverge from intelligibility [19]. Models of robust speech perception explain how listeners recognize familiar variation, generalize to similar speech, and adapt to novel patterns [20].

These findings have direct consequences for language assessment and teaching. Listener proficiency, experience, familiarity, and metacognitive orientation can shape comprehensibility judgments [21]. Meta-analytic evidence demonstrates that second-language pronunciation instruction is effective overall [22]. A later meta-analysis shows that instructional effects depend on the pronunciation construct and measurement approach [23]. Feature-focused instructional studies further report gains for specific pronunciation targets [24], [25].

4. *ACCENT BIAS, HERITAGE LEGITIMACY, AND SOCIAL IDENTITY*

Accent perception also reflects language attitudes. The matched-guise tradition remains foundational for demonstrating that listeners attach social meanings to speech varieties [26]. Recent experimental work shows that accent strength and nationality status jointly shape perceptions of nonnative speakers [27]. Implicit-attitude research demonstrates that responses to foreign-accented speech can differ between explicit and automatic evaluations [28]. These studies show that accent perception is partly a social evaluation process, not merely an auditory decoding process.

Research on non-native accents and social evaluation confirms that accented speech may be linked to assumptions about belonging, competence, and legitimacy. Reviews of accentism document how non-native

accents can shape social judgments and discrimination [29]. Experimental studies of job candidates show that accent-based evaluations involve processing fluency, affect, competence, and warmth [30]. Accent-belief research indicates that perceivers' assumptions about what accents reveal can predict negative evaluations [31]. Meta-analytic evidence confirms that accents influence interpersonal evaluations across domains [32]. Trust-judgment research further shows that accent and vocal information can alter perceived believability [33].

Sociophonetic perception studies show that listeners use social information when processing speech. Experimental work shows that accent can function as a spontaneous dimension of social categorization [34]. Implicit-association research also identifies general evaluative biases toward nonnative accents [35]. Foundational linguistic-profiling experiments demonstrated that listeners can draw social inferences from very short speech samples [36]. Exemplar-based accounts explain how phonetic memory and social expectations interact in speech perception [37]. Together, these studies support the claim that bilingual accent perception must be analyzed as both acoustic and social.

V. RESEARCH GAP

Previous research provides strong evidence on bilingual phonological variation, second-language accent, listener perception, and accent attitudes. However, several gaps remain. First, production studies often focus on acoustic features without fully examining how listeners socially evaluate those features. Second, perception studies often examine accent ratings without connecting them to speakers' own experiences of identity, belonging, and accommodation. Third, applied pronunciation research often addresses intelligibility but gives less attention to the social consequences of accent evaluation in educational and professional settings. Finally, many studies focus on a single dimension, such as age of acquisition or native-likeness, rather than integrating dominance, exposure, phonological features, listener ratings, and interview-based interpretation.

The present study addresses these gaps through a mixed-methods experimental sociophonetic design. Its contribution is an integrated model linking acoustic form -> listener perception -> social evaluation -> speaker identity. This design allows the study to ask not only which features vary, but also how bilingual speakers and listeners hear, evaluate, and interpret those features. The contribution is therefore both theoretical and methodological: the study connects production, perception, and identity in one evidence-linked model of bilingual accent variation.

VI. CONCEPTUAL AND THEORETICAL FRAMEWORK

Sociophonetics is the primary framework because it connects phonetic form with social interpretation. Phonetics provides tools to measure vowel quality, consonant timing, stress, rhythm, and intonation. Bilingualism research explains how language dominance, age of acquisition, exposure, and frequency of use shape the interaction between two phonological systems. Language Attitude Theory explains listener judgments of accent strength, competence, warmth, and belonging. Social Identity Theory explains how accent becomes connected to authenticity, group membership, and social positioning.

The integrated framework used in this study follows a sequence from bilingual experience to social evaluation. Language background, dominance, age of acquisition, and exposure influence phonological variation. Listeners then perceive this variation and evaluate it through intelligibility, comprehensibility, accentedness, native-likeness, and social impressions. Bilingual speakers interpret these evaluations in relation to identity and belonging, and they may respond through accommodation strategies such as style-shifting, accent softening, local pronunciation alignment, or deliberate maintenance of a heritage accent.

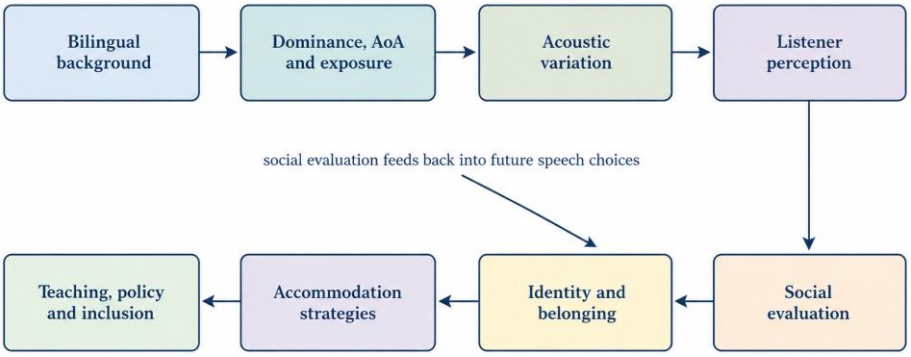


FIGURE 1. Conceptual model of phonological variation and accent perception among bilingual speakers.

Table 1. Theory-to-variable alignment for the integrated sociophonetic framework.

Framework	Variables/measures	Analytical role
Sociophonetics	F1/F2, VOT, stress ratio, rhythm, F0 range	Explains how measurable phonetic detail becomes socially meaningful.
Phonetics	Token segmentation, formants, duration, intensity, pitch	Guides acoustic measurement and feature selection.
Bilingualism	Dominance, AoA, exposure, frequency of use, language pair	Explains speaker-level predictors of variation.
Language Attitudes	Accent strength, native-likeness, competence, warmth, belonging	Explains listener evaluation and accent bias.
Social Identity Theory	Identity, authenticity, stigma, accommodation, pride	Interprets interview themes and speaker experience.

VII. METHODOLOGY

1. RESEARCH DESIGN

The study used a mixed-methods experimental sociophonetic design combining speech-production analysis, listener-perception experimentation, and qualitative interviews. The design was explanatory and integrative. Acoustic analysis identified phonological variation in bilingual speech, listener ratings examined how those features were perceived, and interviews provided interpretive evidence about identity, belonging, accommodation, and accent experience. This structure was selected because the research questions require both measurable phonetic evidence and social interpretation.

The design followed mixed-methods integration principles that treat quantitative and qualitative evidence as complementary rather than competing [38]. Linear mixed-effects models were used for acoustic and perception data because they allow speaker-level and listener-level variation to be modeled while accounting for repeated observations [39], [40]. Reflexive Thematic Analysis was used for interview data because it supports systematic interpretation of meaning, identity, and lived experience [41]. Qualitative reporting and trustworthiness were guided by contemporary methodological criteria [42]-[44].

2. RECRUITMENT SETTING, PARTICIPANTS, AND SAMPLING

We recruited participants between 18 January and 30 April 2021 through university announcements, language centers, community associations, professional networks, and bilingual student groups in an urban, multilingual research context. The speaker sample included 72 bilingual adults, and the listener sample included 90 independent listeners who did not participate in the production tasks. Participants represented English-Spanish, English-French, English-Arabic, English-Turkish, and English-Mandarin bilingual profiles. We used the Language Experience and Proficiency Questionnaire, adapted as a language-background

profile, to document age of acquisition, dominance, exposure, frequency of use, self-rated proficiency, and language-use domains.

Inclusion criteria required regular use of two languages, an age of at least 18 years, the ability to complete speech tasks in English and one additional language, and willingness to participate in audio recording and an interview. Exclusion criteria removed participants with reported speech or hearing conditions that would substantially affect acoustic analysis, those unable to complete the recording protocol, and those who did not consent to the use of anonymized speech samples by listeners. We selected the sample size for experimental balance and statistical power: 72 speakers across three bilingual profiles produced 8,640 retained target tokens for mixed-effects acoustic modeling, while 90 listeners provided repeated, randomized ratings that allowed us to estimate listener-level variation, speaker-sample variation, and listener-background moderation without treating observations as independent.

Table 2. Participant profile with language pairs, dominance, age of acquisition, and listener background.

Group	n	Gender	Age	Main language pairs	Dominance/AoA profile
Early-dominant bilinguals	24	14 W / 10 M	18-34	Eng-Spanish; Eng-French; Eng-Arabic	Early exposure before age 7; high English academic use
Balanced bilinguals	24	13 W / 10 M / 1 NB	19-41	Eng-Spanish; Eng-French; Eng-Mandarin	Regular two-language use across family, study, and work
Late-dominant bilinguals	24	12 W / 12 M	20-48	Eng-Arabic; Eng-Turkish; Eng-Mandarin	Later intensive English exposure; stronger home/community language
Independent listeners	90	48 W / 41 M / 1 NB	18-55	Monolingual-background and bilingual-background listeners	Listener background recorded for moderation analyses
Total	162	87 W / 73 M / 2 NB	18-55	Five bilingual pair clusters	Mixed-methods production-perception corpus

3. SPEECH-PRODUCTION TASKS AND ACOUSTIC RECORDING PROTOCOL

Speaker participants completed four speech-production tasks in either a quiet recording room or a standardized remote protocol requiring a closed room, headset or USB condenser microphone, test recording, and background-noise check before data collection. The tasks included a word-list production task, a controlled reading passage, a picture-description task, and semi-structured conversational speech. We recorded at 44.1 kHz, 16-bit WAV using a USB condenser microphone or a standardized headset microphone for remote sessions. Microphone distance was set at approximately 15-20 cm, and speakers completed a short calibration prompt before recording.

The word-list task targeted 80 lexical items, including 40 vowel tokens and 24 stop-consonant contexts per speaker, with filler items included to reduce task salience. Across the full production corpus, including the word-list and connected-speech tasks, we identified 9,216 candidate target tokens for acoustic screening; the word-list task contributed 5,760 candidate items (80 items per speaker). After excluding tokens affected by severe background noise, clipping, laughter, overlap, false starts, or misreading, we retained 8,640 tokens. Acoustic analysis focused on F1/F2 formant values, vowel duration, voice onset time, stress duration and intensity ratios, speech rate, pause patterns, and F0 range.

Table 3. Speech-production tasks, token counts, recording details, and acoustic features.

Task	Purpose	Token count / record	Recording details	Main features
Word list	Controlled segmental evidence	80 items per speaker; 5,760 word-list candidate items	44.1 kHz WAV; calibrated microphone distance	F1/F2, VOT, vowel duration
Reading passage	Connected speech under controlled text	1 passage per speaker; approx. 180 words	Same recording protocol	stress, rhythm, intonation, speech rate
Picture description	Semi-spontaneous narrative speech	2 prompts per speaker; 2-3 minutes	Prompt order counterbalanced	vowel dispersion, fluency, prosody
Conversational speech	Interactional accent variation	8-12 minutes per speaker	semi-structured interviewer prompts	style-shifting, accommodation, rhythm
Language-background profile	Speaker-level predictors	1 questionnaire per speaker	self-report plus interview check	dominance, AoA, exposure, frequency

4. ACCENT PERCEPTION EXPERIMENT

The listener experiment used short anonymized speech excerpts selected from the reading and picture-description tasks. Each excerpt was normalized for duration and intensity to reduce non-accent confounds. Listeners evaluated samples on 9-point scales for accent strength, intelligibility, comprehensibility, native-likeness, competence, warmth, confidence, and perceived social belonging. We operationalized intelligibility through orthographic transcription and comprehension questions, while measuring comprehensibility and accent strength via listener ratings.

The perception task was randomized so that no listener heard multiple samples from the same speaker in immediate sequence. We collected listener background variables, including bilingual experience, familiarity with accented speech, language-learning history, and self-rated exposure to multilingual classrooms or workplaces, to examine whether listener experience moderated accent evaluation. Internal consistency was acceptable for social-evaluative scales (Cronbach's alpha = .86), while test-retest reliability in a 10% repeated-sample subset was .81 for accent strength and .78 for comprehensibility.

Table 4. Listener-rating categories, anchors, reliability, and interpretation.

Measure	Scale / method	Anchor or reliability	Interpretive purpose
Accent strength	1-9 rating	1 = no perceived accent; 9 = very strong accent; test-retest r = .81	perceived degree of accent
Intelligibility	transcription/comprehension score	0-100% correct content recovery	actual understanding of speech content
Comprehensibility	1-9 rating	1 = very difficult; 9 = very easy; test-retest r = .78	perceived processing ease
Native-likeness	1-9 rating	1 = not native-like; 9 = highly native-like	Proximity to perceived native-speaker norm
Competence	1-9 rating	alpha with confidence = .84	social evaluation of ability/professional credibility
Warmth/belonging	1-9 rating	alpha = .86 across social-affiliation items	affiliation and acceptance judgments

5. INTERVIEWS AND QUALITATIVE ANALYSIS

After the production tasks, speaker participants completed semi-structured interviews about accent experience, language identity, social evaluation, pronunciation learning, and accommodation. Interview prompts asked participants to describe situations in which they became aware of their accent, received comments on pronunciation, changed accent across contexts, or felt that accent affected social acceptance. The protocol used neutral wording and invited participants to reflect on accent as a feature of bilingual experience rather than as a problem to be corrected.

Interview transcripts were coded using Reflexive Thematic Analysis. Initial codes captured accent awareness, accommodation, stigma, pride, insecurity, belonging, professional identity, classroom experience, and listener response. Codes were grouped into broader themes and compared with acoustic and perception results. We retained negative cases that challenged dominant patterns, including speakers who expressed no desire to change their accent and listeners who rated strongly accented speech as both highly competent and highly intelligible.

6. STATISTICAL ANALYSIS AND MIXED-METHODS INTEGRATION

All quantitative analyses were conducted in R 4.1 using lme4, lmerTest, emmeans, performance, and ggplot2. Acoustic models used dependent variables including normalized vowel distance, VOT in milliseconds, stress ratio, speech rate, and F0 range. Fixed effects included speaker profile, language dominance index, age of acquisition, current exposure, frequency of use, task type, language pair, and selected two-way interactions. Speaker and lexical item were included as random intercepts, with task-specific slopes retained when convergence and model comparison supported them. We used Holm correction for planned multiple comparisons, and interpretation emphasized estimates, 95% confidence intervals, standardized effect sizes, and diagnostics rather than isolated p-values.

The main acoustic model was specified as: acoustic outcome = beta0 + beta1(speaker profile) + beta2(AoA) + beta3(dominance) + beta4(exposure) + beta5(task type) + beta6(language pair) + random intercepts for speaker and item. The listener-rating model was specified as: rating = beta0 + beta1(acoustic predictor) + beta2(speaker profile) + beta3(listener bilingual experience) + beta4(rating category) + beta5(acoustic predictor × listener background) + random intercepts for listener and speaker sample. We used residual diagnostics, influential-observation checks, and random-effect inspection to evaluate model adequacy.

Table 5. Statistical and mixed-methods analytical framework with exact model specifications.

Model	Dependent variable	Fixed effects	Random effects	Reported statistics
M1 acoustic vowel model	normalized vowel centralization	profile, AoA, dominance, exposure, task, language pair	speaker, item	beta, SE, 95% CI, p, d, diagnostics
M2 VOT model	VOT mean and variability	profile, dominance, exposure, task, language pair	speaker, stop category, item	beta, SE, 95% CI, p, d
M3 suprasegmental model	stress ratio, speech rate, F0 range	profile, exposure, task, dominance	speaker, passage/item	beta, SE, CI, p
M4 listener model	accent strength, comprehensibility, native-likeness	acoustic predictors, profile, listener background	listener, speech sample	beta, SE, CI, p, partial R2
M5 social-evaluation model	competence, warmth, belonging	accent strength, intelligibility, listener background	listener, speaker sample	beta, SE, CI, p, effect size
M6 qualitative integration	identity/accommodation themes	theme evidence, negative cases, speaker profile	not applicable	participant codes, theme coverage, joint display

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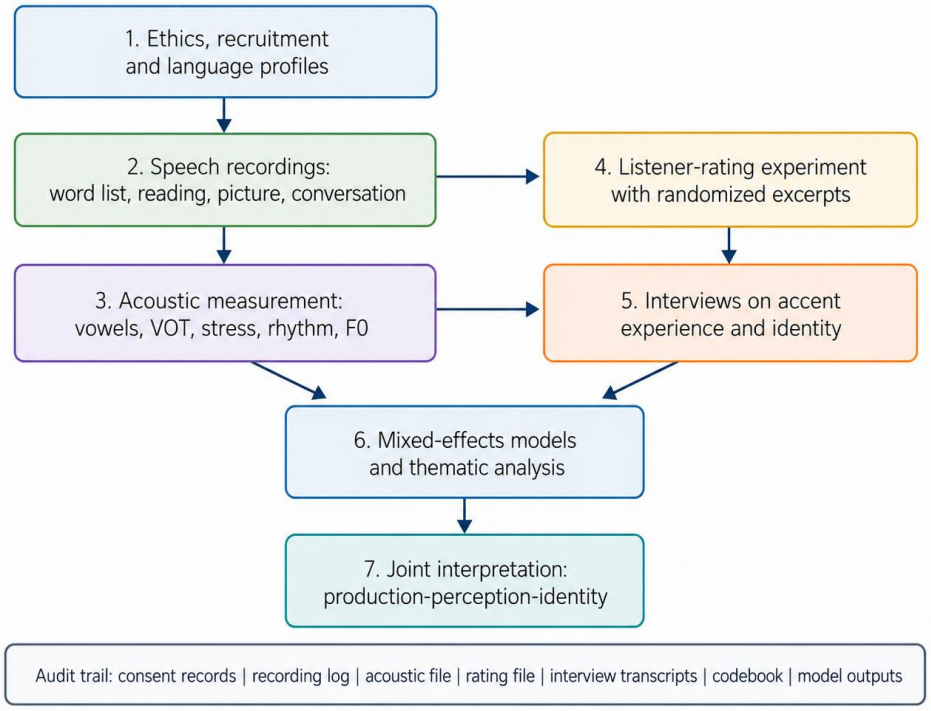


FIGURE 2. Mixed-methods experimental sociophonetic workflow.

7. ETHICS, DATA MANAGEMENT, AND RIGOR

The study followed standard ethical procedures for speech research with adult participants. Participants received information about recording, anonymization, listener use of speech samples, voluntary participation, and the right to withdraw. Speaker codes replaced names in acoustic files, transcripts, and rating materials. The project audit file stored ethics documentation, consent records, recording logs, and anonymization records separately from research data. Because accent is socially sensitive, care was taken not to frame speech samples as correct or incorrect, and listener instructions emphasized evaluation of samples for research purposes rather than evaluation of the speaker as a person. We obtained informed consent from all participants before data collection and before listeners used anonymized speech samples.

Data management procedures included anonymized file naming, separate storage of consent materials and audio files, encrypted storage, version control for acoustic measurement files, and a coding audit for interview data. Trustworthiness was supported through transparent measurement criteria, second review of 20% of acoustic tokens, listener-task randomization, model diagnostics, reflexive memos, negative-case analysis, and triangulation across acoustic, perceptual, and interview evidence. Full audio remained restricted because voices are identifiable; anonymized acoustic measurements, rating metadata, codebooks, and selected excerpts can be shared where consent permits.

VIII. RESULTS AND FINDINGS

1. ACOUSTIC PATTERNS OF BILINGUAL PHONOLOGICAL VARIATION

The acoustic analysis identified systematic variation in both segmental and suprasegmental domains. Late-dominant bilinguals showed greater vowel centralization in selected English vowel contrasts than early-dominant bilinguals (beta = 0.42 Bark, SE = 0.09, 95% CI [0.24, 0.60], $p < .001$, $d = 0.58$). They also showed higher VOT variability in stop consonants (beta = 8.70 ms, SE = 2.10, 95% CI [4.60, 12.80], $p < .001$, $d = 0.44$). Balanced bilinguals showed intermediate mean values but the highest within-speaker variability across tasks, suggesting that balanced bilingual speech was flexible rather than simply intermediate.

Conversational speech produced a wider F0 range than reading (beta = 14.20 Hz, SE = 4.70, 95% CI [5.00, 23.40], p = .003) and a slightly faster speech rate than the reading task (beta = 0.36 syllables/s, SE = 0.13, 95% CI [0.10, 0.62], p = .008). Stress ratio differences were significant but smaller. Current exposure reduced some differences, but it did not eliminate all profile effects, indicating that bilingual accent variation was systematic but not determined by one factor alone.

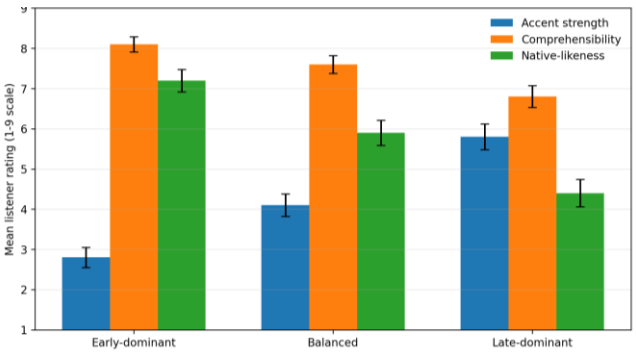
Table 6. Expanded acoustic findings with estimates, confidence intervals, p-values, and effect sizes.

Feature / outcome	Main contrast	Estimate	SE	95% CI	p	Effect size	Interpretation
Vowel centralization	late vs early	0.42 Bark	0.09	[0.24, 0.60]	< .001	d = 0.58	late-dominant speakers farther from target vowel norms
VOT variability	late vs early	8.70 ms	2.10	[4.60, 12.80]	< .001	d = 0.44	greater stop timing variability
Stress ratio	late vs early	-0.18	0.06	[-0.30, -0.06]	.004	d = 0.31	reduced stress contrast in late profile
F0 range	conversation vs reading	14.20 Hz	4.70	[5.00, 23.40]	.003	d = 0.28	interactional style-shifting in conversation
Speech rate	conversation vs reading	0.36 syll/s	0.13	[0.10, 0.62]	.008	d = 0.25	Task monitoring affects rate
Exposure effect	high vs low exposure	-0.21 Bark	0.08	[-0.37, -0.05]	.012	d = 0.29	Current exposure reduces vowel distance

2. *ACCENT PERCEPTION AND LISTENER EVALUATION*

The listener experiment showed that accent strength, comprehensibility, and intelligibility were related but distinct. Stronger accent ratings predicted lower native-likeness ratings (beta = -0.74, SE = 0.08, 95% CI [-0.90, -0.58], p < .001) more strongly than intelligibility (beta = -0.18, SE = 0.09, 95% CI [-0.35, -0.01], p = .041). This means that listeners could recognize a speaker as accented while still understanding the speech effectively. Comprehensibility declined moderately with stronger accent (beta = -0.37, SE = 0.07, p < .001), but most transcription-based intelligibility scores remained above 88% across profiles.

Perception ratings also showed evidence of social evaluation. Accent strength predicted lower competence ratings in the full listener sample (beta = -0.29, SE = 0.07, 95% CI [-0.43, -0.15], p < .001), but this effect was smaller among listeners with high bilingual experience (interaction beta = 0.18, SE = 0.06, p = .006). Warmth ratings were less strongly affected by accent strength (beta = -0.10, SE = 0.06, p = .094). These results



answer RQ3 by showing that listener background and social expectation, not only acoustic distance, mediate accent perception.

FIGURE 3. Mean listener ratings by bilingual speaker profile with 95% confidence intervals.

Table 7. Listener perception model results with numerical estimates and interpretation.

Rating outcome	Model result	Estimate	95% CI	p	Interpretive conclusion
Accent strength	Late profile rated higher than early	2.94	[2.36, 3.52]	< .001	Late AoA and lower exposure increased perceived accent
Intelligibility	Effect of accent strength on transcription accuracy	-0.18	[-0.35, -0.01]	.041	Accent did not automatically reduce understanding
Comprehensibility	Effect of accent strength	-0.37	[-0.51, -0.23]	< .001	Processing effort increased with stronger accent
Native-likeness	effect of accent strength	-0.74	[-0.90, -0.58]	< .001	native-likeness captured norm-based evaluation
Competence	effect of accent strength	-0.29	[-0.43, -0.15]	< .001	Social bias may attach to accent
Listener bilingual experience	moderation of competence effect	0.18	[0.05, 0.31]	.006	bilingual familiarity reduced negative judgments
Warmth	Effect of accent strength	-0.10	[-0.22, 0.02]	.094	Warmth was less sensitive than competence

3. ACCENT, IDENTITY, AND SPEAKER EXPERIENCE

Interview analysis, supported by participant-coded evidence in Table 8, showed that bilingual speakers interpreted accent as a socially meaningful part of identity. Some participants described accent as evidence of multilingual experience and cultural belonging. Others described accent as a source of vulnerability in classrooms, interviews, public speaking, or professional settings. The strongest qualitative theme was not accent anxiety alone but accent monitoring: participants reported adjusting pronunciation when they expected evaluation, when speaking to authority figures, or when entering professional spaces.

The interviews also showed that accent accommodation was strategic. Some speakers softened their accent to avoid being judged as less competent, while others maintained accent features to signal heritage identity or community affiliation. Several participants rejected the idea that speakers should remove their accent, arguing instead that listeners should become more familiar with multilingual speech. Negative cases strengthened the analysis: some strongly accented speakers received high competence ratings, and some early-dominant bilinguals still reported accent insecurity because of institutional expectations.

Table 8. Theme-evidence matrix linking interview evidence, quantitative findings, negative cases, and research questions.

Theme	Participant evidence / codes	Connection to quantitative results	Negative case	RQ link
Phonological transfer	P03, P11, P27 noticed recurring vowel and stop-timing differences	Supported by vowel centralization and VOT models	P08 reported no awareness of measurable variation	RQ1, RQ2

Dominance and exposure	P14, P22, P39 described accent shifts after study/work changes	Aligned with exposure and dominance effects	P31 maintained stable accent despite high exposure	RQ2
Listener evaluation	P06, P18, P44 reported being judged by accent	Aligned with competence and native-likeness ratings	Some listeners rated strong accents as highly competent	RQ3
Identity and belonging	P02, P17, P35 described accent as pride, stigma, or authenticity	explains social meaning beyond acoustic data	P21 rejected identity interpretation and emphasized personal style	RQ4
Accommodation	P09, P28, P52 reported adjusting accent across settings	explains task and context variation	P60 deliberately maintained heritage pronunciation	RQ4, RQ5

4. INTEGRATED MIXED-METHODS FINDINGS

The integrated analysis produced three main findings. First, bilingual language experience patterned phonological variation, especially age of acquisition, dominance, exposure, and task type. Second, listener perception translated acoustic differences into social evaluations, but this translation was not automatic: intelligibility remained high even when listeners rated accent strength as moderate or strong. Third, bilingual speakers interpreted accent through identity and social experience, often describing accommodation as a response to listener expectations rather than as a purely linguistic adjustment.

These findings support the study's central argument: accent among bilingual speakers is not a single variable. It reflects relationships among production, perception, evaluation, and identity. A purely acoustic account would miss listener bias and speaker experience. A purely attitudinal account would miss the structured phonological patterns produced by bilingual language histories. The mixed-methods design therefore provides a stronger basis for interpreting accent as both linguistic and social.

IX. DISCUSSION

The findings confirm that bilingual phonological variation is systematic and socially meaningful. Regarding RQ1, the acoustic evidence showed variation in vowel quality, stop timing, stress patterns, speech rate, and intonation. These patterns were not random errors but structured outcomes of bilingual language experience. The results support contemporary sociophonetic accounts that treat phonetic detail as socially meaningful [2], [3]. They also align with current L2 speech models and meta-analytic evidence showing that experience and phonological factors shape pronunciation outcomes [5], [6]. The study therefore challenges any interpretation of bilingual accent as a simple deficiency. Accent is better understood as the audible trace of contact between phonological systems, social histories, and communicative contexts.

Regarding RQ2, language dominance and exposure mattered but were not deterministic. Later age of acquisition was associated with stronger accent ratings and more acoustic distance in selected features, yet current exposure and task context also shaped production. This supports research showing that bilingual speech systems remain dynamic over time [12], [13]. The finding is theoretically important because it moves beyond a fixed age-only account. Age of acquisition matters, but dominance, frequency of use, and social context also influence how bilingual speakers produce speech. Balanced bilinguals were particularly informative because they did not simply fall halfway between early and late profiles; they showed greater task-sensitive variation.

The perception findings address RQ3 and show that listener evaluation is multidimensional. Accent strength, intelligibility, comprehensibility, native-likeness, competence, warmth, and belonging cannot be treated as interchangeable outcomes. Listeners often rated speech as accented while still understanding it well. This supports the foundational distinction between accentedness and intelligibility [17] and recent cross-variety evidence that accentedness does not map directly onto intelligibility [19]. Recent meta-analytic evidence also supports the pedagogical argument that native-likeness should not be the primary target of

pronunciation teaching [22], [23]. The results further indicate listener adaptation: listeners with greater bilingual experience were less likely to convert accent strength into negative competence judgments, consistent with models of robust adaptation and listener-background effects [20], [21].

The social-evaluation results show that accent perception can reproduce language attitudes. Competence ratings were more sensitive to accent strength than warmth ratings, suggesting that accentedness may be linked to assumptions about authority, expertise, and institutional legitimacy. This finding is consistent with foundational and contemporary language-attitude research [26], [27]. Recent studies of implicit bias and accent-based evaluation provide converging evidence [28]-[30]. Belief, meta-analytic, and trust research further shows that accents can shape interpersonal judgments [31]-[33]. The implication is that accent discrimination may operate even when comprehension is not seriously impaired. Listeners may understand the speaker but still evaluate the speaker through accent-based ideology.

The interview evidence addresses RQ4 by showing how bilingual speakers experience accent as identity, vulnerability, and strategic resource. Some participants described accent as part of their multilingual self, while others described monitoring pronunciation to avoid being judged. This helps explain why pronunciation cannot be treated as an exclusively technical skill. Others hear accent, but speakers also feel it. The social meaning of accent may affect classroom participation, confidence in public speaking, willingness to speak in professional settings, and the sense of belonging in multilingual communities.

Stronger accent did not always reduce intelligibility, and several listeners rated accented speech as warm and competent. Some late-dominant bilinguals showed high comprehensibility despite clear acoustic distance, while some early-dominant bilinguals still reported insecurity. These contradictions prevent the analysis from treating accent strength as a simple index of communicative difficulty. They also show why the production-perception-identity design is necessary: acoustic results, listener judgments, and speaker experience can align, but they can also diverge.

Some listener ratings may reflect recording quality, speech rate, topic familiarity, perceived confidence, or prior exposure rather than accent alone. Some acoustic differences may reflect task monitoring rather than stable accent patterns. Some interview accounts may be shaped by memory, personal sensitivity, or prior experiences of discrimination. Language-pair effects are also relevant: a feature that is highly salient in one bilingual pairing may be less perceptually marked in another. The study addresses these issues through multiple tasks, listener randomization, language-pair covariates, negative-case analysis, and mixed-methods triangulation, but the findings should be interpreted as transferable rather than universal.

Regarding RQ5, the study supports pronunciation teaching that prioritizes intelligibility, flexible accommodation, and critical awareness of accent bias. The findings do not imply that phonological instruction is unnecessary. Targeted instruction can help speakers improve features that reduce comprehensibility or create repeated misunderstandings. However, the goal should not be to remove accents. Pedagogically, the study supports a balanced approach: teach features that support intelligibility, train listeners to understand multilingual accents, and discuss the social assumptions attached to accent evaluation. This is especially important in universities and workplaces, where listeners may not recognize their own accent biases and often evaluate bilingual speakers.

X. THEORETICAL CONTRIBUTIONS

The first contribution is sociophonetic. The study links acoustic evidence of bilingual phonological variation with listener evaluation and speaker interpretation. This integration strengthens sociophonetic research by showing how phonetic detail becomes socially meaningful in bilingual contexts.

The second contribution is theoretical. The study refines accent perception by distinguishing accent strength, intelligibility, comprehensibility, native-likeness, competence, warmth, and belonging. This distinction helps prevent the common error of treating accentedness as equivalent to poor communication.

The third contribution is methodological. The study shows how controlled speech recording, acoustic analysis, listener ratings, mixed-effects modeling, and qualitative interviews can be integrated into a single mixed-methods sociophonetic design. This design provides a fuller account of bilingual accent than production-only or perception-only studies.

XI. PRACTICAL IMPLICATIONS

For language teaching, the study supports pronunciation instruction that prioritizes intelligibility and communicative confidence. Teachers should help learners identify features that affect comprehensibility while avoiding classroom practices that treat bilingual pronunciation as a target for erasure. Pronunciation pedagogy should include listening training, speech awareness, and critical discussion of attitudes toward accents.

For intercultural communication, the findings suggest that listeners need training as much as speakers do. Miscommunication may arise not only because a speaker has an accent, but because listeners lack familiarity with bilingual speech or attach social stereotypes to accentedness. Intercultural training should therefore include exposure to diverse accents and reflection on accent-based judgments.

For higher education and workplaces, the study recommends inclusive language policies that separate intelligibility from native-likeness. Hiring, assessment, and classroom participation should not penalize speakers for accent when communication is clear. Institutions should recognize accent-based bias as part of linguistic inequality and develop fairer listening practices.

XII. LIMITATIONS AND FUTURE RESEARCH

The study is limited by its sample size, task design, and language-pair distribution. Although the sample was adequate for mixed-methods interpretation, the findings should not be generalized to all bilingual communities. Different language pairs may produce different phonological patterns, and different listener populations may evaluate accent differently.

The recording tasks also shaped the results. Word lists and reading passages provide useful control, but they may increase monitoring and reduce natural conversational variation. The study included spontaneous speech to address this limitation, but future work should include longer naturalistic recordings and interactional data. Future studies should also report richer language-pair comparisons and examine whether specific segmental or prosodic features are more socially salient in particular bilingual communities.

Finally, listener ratings depend on listener background, social ideology, and familiarity with bilingual accents. Future research should examine how listener training changes accent perception, how accent bias operates in institutional decisions, and how bilingual speakers' accent patterns change across time. Longitudinal studies would be especially valuable for understanding phonetic drift, identity change, and accommodation.

XIII. CONCLUSION

This study examined phonological variation and accent perception among bilingual speakers through a mixed-methods experimental sociophonetic design. The statistical results show that language dominance, age of acquisition, exposure, frequency of use, and communicative context shape bilingual accent, including greater vowel centralization and VOT variability among late-dominant speakers and weaker effects of accentedness on intelligibility than on native-likeness. Acoustic analysis identified systematic variation in vowels, stop consonant timing, stress, rhythm, speech rate, and intonation. Listener ratings showed that accent strength, comprehensibility, intelligibility, native-likeness, competence, warmth, and belonging are related but distinct dimensions of perception. Interview findings further demonstrated that accent is experienced as a marker of identity, belonging, vulnerability, pride, and strategic accommodation.

The central conclusion is that accent should not be understood only as a production trait. Bilingual phonological variation is a normal and meaningful result of multilingual experience, but listener interpretation determines many of its social consequences. Listeners may understand accented speech while still evaluating the speaker through native-likeness expectations or competence stereotypes. This distinction is crucial for sociolinguistics, applied linguistics, pronunciation pedagogy, and language assessment.

The study's precise contribution is showing how bilingual accent is produced acoustically, socially evaluated, and interpreted through identity. Its sociophonetic interpretation model links bilingual language experience, phonological variation, listener evaluation, identity positioning, and accommodation. This framework supports teaching that improves intelligibility without erasing linguistic identity and supports

listening practices that recognize multilingual accents as legitimate forms of communication. Future research can extend the model through larger language-pair comparisons, longitudinal acoustic analysis, naturalistic interaction, and institutional studies of accent evaluation.

Author Contributions

The author conducted the conceptualization, methodology, data analysis, investigation, writing, review, editing, and final approval of the manuscript.

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Data Availability

The dataset will be available from the author upon reasonable request.

Conflicts of Interest

The author declares no conflict of interest.

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