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Acoustic Characteristics of Greek Vowels Produced by Adult Heritage Speakers of Albanian

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Abstract: Investigating heritage language (HL)-contact effects on the dominant language has received limited attention despite its importance in understanding the dynamic interplay between linguistic systems in situations of bilingualism. This study compares the acoustic characteristics of Greek vowels produced by heritage speakers (HSs) of Albanian and monolingual Greek speakers, aiming to identify potential differences and explain them. The participants were adult second-generation HSs of Albanian with Greek as their dominant language, born and raised in Greece. A control group of age-matched monolingual Greek speakers was included for comparison purposes. All participants engaged in a controlled speech production task, with the data segmented to extract acoustic values pertaining to the first three formants and the duration of Greek vowels. Bayesian regression models were employed for the subsequent statistical analysis. The results demonstrated differences in the first three formants of certain vowels and the duration of all vowels. These differences can be attributed to the crosslinguistic effect of HL on the dominant language, as well as the interplay between the dynamic and internalized language system of the speakers and the complex effect of the sociophonetic context. These outcomes contribute to the hypothesis positing the emergence of deflected phonetic categories among a distinctive group of bilinguals, namely HSs. Furthermore, this study underscores the significance of a comprehensive exploration of the sociophonetic context of HSs for a nuanced understanding of their phonetic patterns.

Keywords: heritage language; bilingualism; vowels; production; Albanian; Greek

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1. Introduction

Heritage speakers (HSs) are simultaneous or early sequential bilinguals raised in homes where a language other than the dominant societal language is spoken (see, e.g., [1–7]). A language naturalistically acquired at home within a broader sociolinguistic context where "it is not a dominant language of the larger (national) society" is a *heritage language* (HL) [4] (p. 156). Although this term may refer to cases of languages spoken in various sociopolitical contexts by different ethnolinguistic communities (see [8–10]), the definition adopted here is that given by Montrul [11] (p. 399): a HL "is a sociopolitically minority and/or minoritized language acquired as the first or one of the first languages in a bilingual or multilingual context".

Mobility of people in the context of migration gives rise to immigrant HLs. HSs who are simultaneous bilinguals acquire the HL as a minority language alongside the majority language of the society, while in sequential bilingualism, the HL is acquired first and the dominant societal language subsequently in early childhood [7,9]. Under each scenario, by the time they reach adulthood, typical HSs are dominant in the language of their broader speech (national) community, such that heritage bilingualism is commonly "heavily imbalanced in favor of the dominant language" [7] (p. 5). While HSs qualify as native

speakers of both their languages [12,13], the ultimate attainment of many adult HSs in the HL is regarded as the result of incomplete [3,9] differential [2] or divergent acquisition [6,7]. Thus, HSs comprise a special subset of bilinguals with individual variability standing as the hallmark of these populations [9].

Bilingualism, including heritage bilingualism, can be viewed as a continuum, where monolingual speakers of each language represent the two extremes (e.g., [5–7,13–16]). Research on HLs has consistently focused on comparing the linguistic outcomes of HSs in their HL against monolingual norms. Most of these studies consider only the HL under the assumption that the majority language, as HSs' dominant language, is stronger and hence unaffected by language-contact effects [9]. Indeed, studies on adult HSs have demonstrated that linguistic patterns of HSs' dominant (societal) language are similar to those of monolinguals, while differences are observed when heritage performance is compared to the monolingual baseline of the said HL. In the domain of phonology, there is evidence substantiating that HSs can be (mis)identified as monolingual native speakers of their dominant language (e.g., [17,18]). However, bilingualism involves crosslinguistic influence, which in turn implies a bidirectional (rather than unidirectional) influence between the languages (see, e.g., [19], and references therein). Such an interaction may result in mutually restructuring of the two languages across linguistic development. With regard to phonological competence, in particular, crosslinguistic influence may give rise to an approximation of the two phonological systems (e.g., [20–22]).

The current study investigates how heritage bilinguals (re)organize their phonetic systems by examining the acoustic characteristics of vowels produced by adult HSs of Albanian in their dominant language, namely Standard Modern Greek (henceforth Greek). The aim is to identify potential differences from monolingual Greek productions and to account for the findings.

2. Literature Review

2.1. Phonology and Heritage Language

According to the premises of several speech models, such as the Speech Learning Model [23], both the first language (L1) and the second language (L2) are found in a common phonological/phonetic space creating bidirectional effects from L1 to L2 [23–25] and from L2 to L1 [16,26,27]. Similarly, the speech of HSs presents crosslinguistic influence, with evidence of the dominant majority language affecting the HL and vice versa [28]. HL pronunciation within ethnic minority settings demonstrates notable distinctions when compared to that of monolingual individuals, with discernible differences emerging not only between the patterns of first-generation immigrants and monolinguals but also between first-generation immigrants and HSs of second or third-generations (e.g., [29–36]). A dominance shift usually happens in second-generation immigrants (HSs), when formal education in the majority language starts around the age of 6 (e.g., [9]).

In the context of heritage bilingualism, research on dominant language pronunciation is more limited. When a weaker language (i.e., a HL) comes into contact with a dominant language, speakers' pronunciation and accent may influence their dominant (societal) language to some extent. This phenomenon is often referred to as substrate influence. Substrate characteristics have been demonstrated to strengthen and expand existing patterns in the dominant language, frequently becoming notable regional traits [37]. For example, Natvig [38] evaluated claims regarding the impact of Norwegian as an HL substrate on the development of American English dialects in the Upper Midwest region of the USA. The author emphasized the production of monophthongal English /o/ in words such as "goat" and "boat", which is found in the dialects spoken in Minnesota and North Dakota. It has been suggested that Scandinavian long [oː] vowel is the source of English /o/ due to the high level of emigration of Scandinavian people into these areas. The results seem to verify that the productions of Norwegian HSs for this vowel were primarily monophthongal. McCarthy et al. [39] examined the production of Sylheti and English stops and vowels by London-Bengali speakers. The participants were early and late arrivals from

Bangladesh to the UK with English and Sylheti as their dominant languages, respectively, second-generation HSs with English as their dominant language, and monolingual Sylheti and English speakers. The authors used a picture forced-choice task to elicit productions targeting the L1 and L2 vowels. The results showed that late arrivals produced the Sylheti stops and vowels in a native-like manner, while their English productions were influenced by their dominant language. Early arrivals and second-generation speakers produced Sylheti vowels in a native-like manner but not stops. The English productions of both groups were similar to those of English L1 speakers. However, there were some subtle differences between the English productions of Sylheti-speaking groups and English L1 speakers. Specifically, a lower F2 for vowel /i/ was observed, as well as a different duration for vowel /ɒ/.

A crucial question in bilingual studies, including the study of HLs, is how similar the phonetic categories of bilinguals are to those of monolinguals of the dominant societal language. To address this question, Mack [40] examined the perception and production of English consonants and vowels by early English–French bilinguals and English monolinguals in the USA. The author found that bilinguals did not differ from English monolinguals in the discrimination and production of /d/ and /t/ and the production of /ɪ/, but differed in the identification of the /d–t/ and /i–ɪ/ contrasts and the production of /i/. Mack concluded that only certain aspects of the phonetic system are similar between early bilinguals and monolinguals in the dominant language. Flege [23] proposes that even if L2 phonetic categories are established in bilinguals, they may not be able to produce the sounds in the same way as L1 speakers. This is because as long as both vowel systems are found in a common phonological space, bilinguals strive to maintain phonetic distance between the sounds, thereby creating deflected phonetic categories to accommodate the L2 sounds. Another explanation for such a divergence is the possibility that bilinguals use features not exploited in their L1 to distinguish the L2 sounds. MacLeod et al. [41] compared early Canadian French–Canadian English bilinguals and English and French monolinguals in the production of high vowels. They reported that bilinguals retained distinct categories across their two languages for similar vowels and they produced vowels in a monolingual-like manner. However, a more careful examination of the findings indicated divergences between bilinguals and monolinguals in some productions.

Baker and Trofimovich [20] examined the role of the age of onset of bilingualism in the organization of phonetic systems in early and late Korean–English bilinguals. This study compared these bilingual groups to English and Korean monolinguals, focusing on the phonetic systems in both English and Korean vowels. It was found that early bilinguals manifested a bidirectional influence in their two languages, producing distinct acoustic realizations of vowels in both languages compared to monolingual productions. This was not the case for late bilinguals, whose performance indicated a unidirectional influence of L1 on L2 as their L2 vowel productions were found to be affected by the acoustic properties of their L1. According to the authors, the extent and directionality of crosslinguistic influence in early and late bilinguals depends on the degree of acoustic similarity between L1 and L2 vowels and the length of their exposure to each language. Guion [21] reported similar results in investigating the production of vowels by simultaneous, early, mid, and late Quichua–Spanish bilinguals dominant in Spanish. More specifically, simultaneous bilinguals could divide their vowel space in a more refined manner to accommodate the vowels of their two languages compared to early bilinguals. Additionally, among bilinguals who acquired knowledge of Spanish vowels (that is, simultaneous, early, and some mid bilinguals), Quichua vowels demonstrated a higher position compared to late bilinguals, suggesting a discernible influence of Spanish on their native Quichua vowel productions. The author concluded that the particular sociolinguistic context in Ecuador, and specifically the city of Otavalo where local people speak both Quichua and Spanish, gives rise to contact-induced change through the intergenerational transmission of bilinguals' reorganized phonetic systems.

The current study aims to investigate the acoustic characteristics of Greek vowels, namely the first three formant frequencies (F1, F2, F3), and duration, produced by second-generation adult HSs of Albanian who live in Athens, Greece. The Greek vowel production of Albanian HSs was compared to that of age-matched monolingual Greek speakers. The objective was to explore whether and to what extent differences can be discerned in the Greek performance of Albanian–Greek bilinguals (i.e., in their dominant language) when compared to the monolingual Greek baseline and to account for the findings. It was expected that there might be differences at least for some acoustic aspects pertaining to some vowels, as expounded below, based on previous evidence on language contact and consequent crosslinguistic influence. To the best of our knowledge, this is the first study to examine the acoustic patterns of second-generation Albanian HSs in Greece in their dominant language.

2.2. Albanian as a HL in Greece

Following the fall of communism in the early 1990s, a substantial migration wave started from Albania to Greece, given the adjacency of the two countries. Such a mobility persists to this day, albeit with diminished intensity. Although precise figures are hard to acquire due to ongoing fluctuations, more than 50% of immigrants residing in Greece today can trace their origin to Albania (480,804 individuals in the 2011 census) [42,43]. Consequently, Albanians constitute the largest ethnic minority and immigrant community in Greece, making up approximately 5% of the total population [44,45]. Children born to Albanian parents grow up in bilingual environments with Albanian (and Greek) spoken at home and Greek used at school and most other social settings. These speakers are thus HSs of Albanian, who eventually become dominant bilinguals in Greek. The racist character of Greek society [46,47], entailing the stigmatization of Albanians in Greece [44], interrelates with the high level of assimilation of this ethnolinguistic group into the Greek social fabric. Such conditions have led to a gradual language shift towards Greek, despite the significant demographic presence of Albanians in this social context [44,48]. Ndoci [45], for instance, reported that the production of Albanian ethnolectal phonological features in Greek is negatively stigmatized by both Greeks and Albanians. The tendency towards language shift is particularly evident in adult second-generation immigrants, i.e., HSs of Albanian, who use predominantly Greek in everyday life [44,49,50]. However, Albanian HSs seem to acknowledge their dual identity and construct complex identities (see [46,47,49]).

2.3. Greek and Albanian Vowel Systems

The Standard Modern Greek vowel system includes the five vowel qualities, /i e a o u/ [51,52]. Greek does not differentiate between long and short vowels [53], although stress alters vowel duration, with stressed vowels being longer than unstressed vowels [54]. Greek vowels /i/ and /u/ are described as close front unrounded and close back rounded, respectively [55]. Greek /a/ is between open and open-mid central unrounded vowels, while Greek unrounded /e/ and rounded /o/ are between close-mid and open-mid vowels [56].

The Standard Albanian vowel system based on the Tosk variety typically consists of the seven vowel qualities, /i y e ə a o u/ [57]. Albanian /i/, /y/, and /u/ are described as close front unrounded, close front rounded, and close back rounded vowels, respectively. Albanian /e/, /ə/, and /o/ are (close-)mid front unrounded, mid central unrounded, and (close-)mid back rounded vowels, respectively. However, /ə/ presents great variation across different speakers and contexts. It has been suggested that it comprises an open-mid unrounded vowel, phonologically transcribed as /ɜ/ [58]. In addition, vowels /e/ and /o/ exhibit free variation, occasionally manifesting as more open-mid sounds [ɛ] and [ɔ] [59]. Lastly, Albanian /a/ is described as an open central-to-back unrounded vowel [57].

To investigate the acoustic features of L1 Albanian and L1 Greek vowels, five Albanian speakers (n_{females} = 3) and 10 Greek speakers (n_{females} = 7) participated in a production task in which they produced their L1 vowels. The Albanian speakers lived permanently

in central and central-southern Albania and were in the age range of 18–29 (M_{age} = 23, *SD* = 5.05). All of them were native speakers of Standard Albanian. They were asked to produce carrier phrases including words targeting their L1 vowels. The words were in the context of /fVf/ (V = vowel) as part of the phrase "E the /fVf/ prap" ("You said <word> again") (7 vowels × 2 repetitions each). The Greek speakers lived permanently in Athens, Greece and were in the age range of 21–33 (M_{age} = 26.3, *SD* = 4.57); their native language was Standard Modern Greek. They produced the phrase "Ípes /fVf/ páli" ("You said <word> again"), which also included words in the /fVf/ context (5 vowels × 2 repetitions each). For more information about the experimental procedure, see the Methodology section below. Figure 1 illustrates F1 and F2 for Albanian and Greek vowels as produced by native speakers of these languages. Table 1 shows the average F1, F2, F3, and duration values of Albanian and Greek vowels.

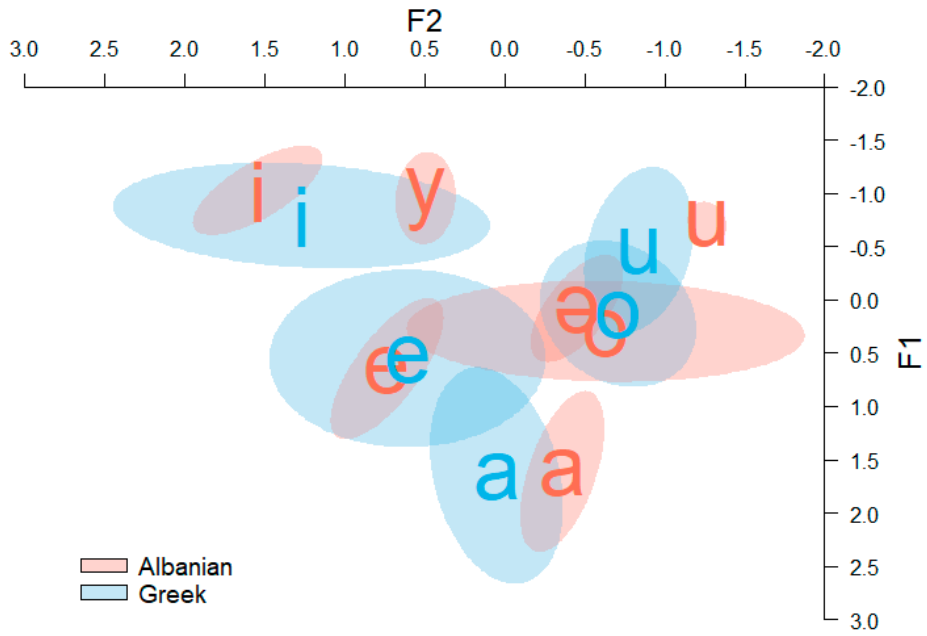

Figure 1. F1 × F2 (normalized) of Albanian and Greek vowels produced by L1 speakers.

Table 1. Average normalized F1, F2, and F3 values (*z*-scores) and duration values (ms) of Albanian and Greek vowels. Parentheses show the *SD*s.

Vowels	F1	F2	F3	Duration
		Albanian		
i	1.02 (0.38)	1.54 (0.37)	0.90 (0.93)	137(33)
y	−0.95 (0.39)	0.49 (0.17)	−0.66 (0.65)	129(29)
e	0.65 (0.60)	0.73 (0.32)	0.05 (1.16)	136(29)
ə	0.08 (0.45)	−0.45 (0.26)	−0.05 (0.60)	136(27)
a	1.61 (0.68)	−0.36 (0.24)	−0.55 (0.74)	151(31)
o	0.30 (0.43)	−0.64 (1.12)	0.35 (1.19)	141(33)
u	−0.72 (0.18)	−1.27 (0.11)	0.00 (0.96)	119(31)
		Greek		
i	−0.89 (0.29)	1.48 (0.86)	0.36 (1.17)	149(34)
e	0.53 (0.60)	0.63 (0.80)	−0.09 (1.15)	171(36)
a	1.88 (0.77)	−0.07 (0.22)	0.01 (1.33)	186(36)
o	0.23 (0.56)	−0.79 (0.19)	0.62 (1.06)	174(32)
u	−0.67 (0.35)	−0.87 (0.31)	0.51 (1.10)	143(41)

The crosslinguistic acoustic analysis of Albanian and Greek vowels demonstrates that the similar vowels between the two languages, namely /i e a o u/, occupy close spaces in the vowel space in terms of F1 and F2. Nevertheless, there are some acoustic differences. Specifically, Albanian /i/ is closer and further front than Greek /i/, while Albanian /a/ is further back than its Greek counterpart. Albanian /u/ is closer and further back than the corresponding Greek vowel. In terms of F3, Albanian vowel /e/ shares close values with the similar Greek vowel /e/. However, Albanian /o/ and /u/ have lower values compared to their Greek counterparts. The same applies to Albanian /a/ compared to Greek /a/. In addition, the durations of Albanian vowels appear to be considerably lower compared to the durations of Greek vowels. If crosslinguistic influence takes place between heritage Albanian and majority/societal Greek, the HSs will produce Greek vowels such as /i u/ with lower F1 values, /a u/ with lower F2 values, and /a o u/ with lower F3 values. Furthermore, the Greek vowels will be produced with remarkably shorter duration values.

3. Methodology

3.1. Participants

Twenty individuals participated in this study. The control group consisted of 10 Greek-speaking individuals of Greek origin, the same who participated in the production task (see Section 2.3). They were born and raised in Greece and lived permanently in Athens. The native variety of these speakers was Standard Modern Greek. The experimental group included another 10 Greek-speaking individuals of Albanian origin, living in Athens (n_{females} = 3), with an age range of 20–34 (M_{age} = 27.3, *SD* = 4.59). They were all identified as simultaneous or early bilinguals of Standard Albanian and Standard Modern Greek and, more precisely, HSs of Albanian, dominant in Greek. The HSs were born to both Albanian parents, i.e., they were 100% minority in terms of ethnic/racial heritage, in line with Kupisch [60]. Their place of birth was either Greece (n = 5) or Albania (n = 5). In the latter case, they had moved to Greece before the age of 4. They had all completed at least 12 years of formal education in Greece and reported low or no literacy in Albanian, as well as no systematic use of other languages apart from Greek and Albanian in their everyday life. All participants had healthy vision and hearing and had never suffered from any cognitive or language disorders. Prior to their participation in the study, they were informed about the goal of the study and their rights, and they gave their written consent, according to the Declaration of Helsinki.

3.2. Materials

The materials consisted of five monosyllabic nonsense words in an /fVf/ context targeting each of the five Greek vowels. They were part of the carrier phrase "Ípes /fVf/ páli" ("You said /fVf/ again"). The chosen specific context is particularly advantageous because it centers on a vowel flanked by identical fricative consonants, /f/. This arrangement simplifies the segmentation process, allowing for a more focused examination of the vowels' properties, free from the potential influence of different adjacent consonants.

3.3. Procedure

3.3.1. Production Test

Each participant completed the test individually in a quiet room. Phrases were shown on a piece of paper and participants were asked by the researcher to read them as if speaking to a friend. The phrases were written using the Standard Modern Greek orthography. Their productions were recorded using Tascam DR05 V2 at a 44.1 kHz sampling rate and saved as .wav files with a resolution of 24 bits. Each individual produced 10 phrases (5 vowels × 2 repetitions), with a total number of 200 phrases for all individuals. The phrases were randomized for each participant. Before the test, we ensured that participants could read the sentences properly.

3.3.2. Feature Extraction

The target words spoken by the speakers were extracted and processed in Praat [61] (for similar descriptions, see [62,63]). Spectrograms and waveforms were visually examined to identify key acoustic features, enabling the measurement of vowel boundaries, including formant frequencies and vocalic duration. To generate these analyses, we employed the following specific settings: a 0.025 positive window length, a 50 Hz pre-emphasis, and a spectrogram view range up to 5500 Hz. Frequencies were measured starting from the end of the noise of the preceding fricative consonant /f/ and the onset of the vowel (V) and concluding at the end of the vocalic periodicity and the onset of the second consonant /f/. Frequencies were measured at their midpoint, a position within the vowel segment where they were least influenced by adjacent sounds. Vowel durations were manually labeled by the first author, involving the determination of each vowel token's start and end points. F1, F2, F3, and duration values were normalized using the *z*-score method due to their broad distribution across a wide range of values for all speakers [64].

3.4. Statistical Analysis

Bayesian regression models were employed for data analysis using the brms package [65] in R [66]. Bayesian models were favored over conventional frequentist approaches because of their capability to handle small sample sizes [67,68]. *F1*, *F2*, *F3* and *duration* were the dependent variables, including the extracted normalized values (expect duration) from speech outputs. *Vowel* (i, e, a, o, u) (reference level: a) and *group* (heritage, monolingual) (reference level: heritage) served as fixed factors, while *participant* served as a random factor. Another notable advantage of Bayesian statistics lies in its ability to incorporate prior knowledge gleaned from previous research. This pre-existing information is integrated into the models using prior distributions. Due to the exploratory nature of this study and the absence of preconceived assumptions about the behavior of data parameters, weakly informative priors were employed. These priors were specified as a Student's *t*-distribution with 3 degrees of freedom, a mean of 0, and a standard deviation of 2.5 [69–71]; Figure 2 shows the density of the selected priors. After fitting the model with these priors, posterior predictive checks were used to evaluate the fit of the models to the observed data. As seen in Figure 3, the analyses demonstrated that the replicated data (yrep) closely resembled the observed data (y) in terms of their distribution, patterns, and variability, suggesting that all models provided good fits to the data. To assess the probability of the test hypotheses relative to their alternatives, we utilized the evidence ratio (ER) as a quantified measure. An ER of >10 is deemed strong evidence in favor of a hypothesis, while an ER of <0.1 is considered strong evidence against a hypothesis [72]. For those familiar with frequentist statistics, an ER < 19 is approximately equivalent to $\alpha = 0.05$ [73]. We also mention the posterior probabilities (PP).

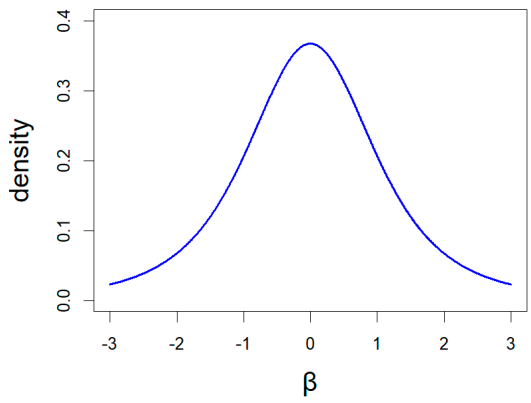

Figure 2. Density of prior distributions for the fixed effects: $\beta \sim t$ (3, 0, 2.5).

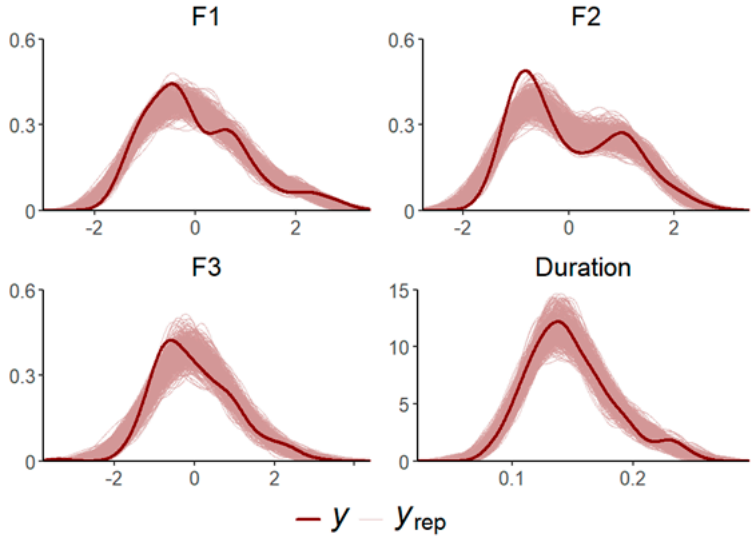

Figure 3. Posterior predictive checks comparing the observed (y) and the replicated data (yrep) in each of the models.

4. Results

As shown in Figures 4 and 5, Greek vowels were produced in a similar manner by both HSs and monolinguals. However, some differences occurred. The most considerable one pertained to /a/, which had a lower F1 (i.e., occupying a closer position) and a lower F2 (i.e., occupying a further back position) in HSs. In addition, vowel /u/ appeared to have lower F2 values in HSs. With respect to F3, /a o u/ seemed to have lower values in HSs. Furthermore, as seen in Figure 6, the duration of Greek vowels was lower in HSs compared to monolinguals. Hypothesis testing assessed whether the acoustic values of Greek vowels produced by HSs were lower compared to corresponding values produced by monolingual speakers. The results indicated strong evidence that Greek /e a o/ (ER = 15.74—inf, PP = 0.94–1) exhibited lower values for HSs compared to monolinguals in terms of F1. Furthermore, there was strong evidence that Greek /i a u/ were produced with lower F2 values by HSs (ER = 12.61–75.92, PP = 0.93–0.94). In terms of F3, strong evidence was found that Greek /o u/ demonstrated lower values in HSs (ER = 21.86–55.34, PP = 0.96–0.98). Moreover, there was strong evidence that the duration of all Greek vowels produced by HSs was lower compared to monolinguals (ER = 15.33–570.43, PP = 0.94–1.00). The results of the main analysis and the hypothesis testing are presented in Tables 2 and 3, respectively.

Table 2. Results of the Bayesian regression models.

		β	*SE*	l—95% CI *	u—95% CI *	Rhat	Bulk ESS	Tail ESS
F1	Intercept	0.92	0.14	0.64	1.18	1.00	873	1530
	vowele	−0.91	0.11	−1.13	−0.71	1.00	1465	2042
	voweli	−2.03	0.11	−2.25	−1.82	1.00	1587	2219
	vowelo	−1.00	0.11	−1.21	−0.78	1.00	1526	2300
	vowelu	−1.75	0.11	−1.96	−1.54	1.00	1601	2208
	groupmonolingual	0.95	0.20	0.56	1.33	1.00	860	1680
	vowele:groupmonolingual	−0.42	0.15	−0.71	−0.11	1.00	1479	2280
	voweli:groupmonolingual	−0.73	0.16	−1.03	−0.42	1.00	1635	2171
	vowelo:groupmonolingual	−0.64	0.16	−0.95	−0.34	1.00	1567	2337
	vowelu:groupmonolingual	−0.79	0.16	−1.10	−0.48	1.00	1532	1915

Table 2. *Cont.*

		β	*SE*	l—95% CI *	u—95% CI *	Rhat	Bulk ESS	Tail ESS
F2	Intercept	−0.4	0.11	−0.60	−0.19	1.00	1416	2002
	vowele	1.09	0.13	0.83	1.35	1.00	1940	2536
	voweli	1.67	0.13	1.42	1.93	1.00	1834	2403
	vowelo	−0.43	0.13	−0.68	−0.17	1.00	1767	2618
	vowelu	−0.70	0.13	−0.96	−0.45	1.00	1806	2316
	groupmonolingual	0.33	0.15	0.04	0.62	1.00	1450	2021
	vowele:groupmonolingual	−0.39	0.19	−0.76	−0.03	1.00	2165	2599
	voweli:groupmonolingual	−0.12	0.18	−0.49	0.24	1.00	1839	2378
	vowelo:groupmonolingual	−0.29	0.19	−0.65	0.08	1.00	1900	2667
	vowelu:groupmonolingual	−0.1	0.19	−0.46	0.26	1.00	1979	2525
F3	Intercept	−0.50	0.27	−1.02	0.05	1.00	1000	1611
	vowele	0.19	0.21	−0.23	0.60	1.00	2144	2590
	voweli	0.44	0.21	0.03	0.84	1.00	2007	2723
	vowelo	0.24	0.22	−0.18	0.67	1.00	2051	2695
	vowelu	0.32	0.22	−0.10	0.75	1.00	2113	2524
	groupmonolingual	0.50	0.39	−0.26	1.24	1.00	991	1443
	vowele:groupmonolingual	−0.28	0.31	−0.89	0.32	1.00	1974	2449
	voweli:groupmonolingual	−0.09	0.30	−0.67	0.50	1.00	1954	2526
	vowelo:groupmonolingual	0.37	0.31	−0.23	0.97	1.00	1960	2788
	vowelu:groupmonolingual	0.17	0.30	−0.41	0.78	1.00	2028	2874
Duration	Intercept	0.15	0.01	0.13	0.17	1.01	556	962
	vowele	−0.01	0.01	−0.02	0.00	1.00	1556	2062
	voweli	−0.03	0.01	−0.04	−0.02	1.00	1377	2061
	vowelo	−0.01	0.01	−0.03	0.00	1.00	1406	1870
	vowelu	−0.02	0.01	−0.03	−0.01	1.00	1556	2181
	groupmonolingual	0.04	0.01	0.01	0.07	1.01	679	1158
	vowele:groupmonolingual	0.00	0.01	−0.02	0.01	1.00	1457	1792
	voweli:groupmonolingual	−0.01	0.01	−0.02	0.01	1.00	1318	2132
	vowelo:groupmonolingual	0.00	0.01	−0.01	0.02	1.00	1433	1953
	vowelu:groupmonolingual	−0.02	0.01	−0.03	0.00	1.00	1604	2443

* CIs refer to Credibility Intervals.

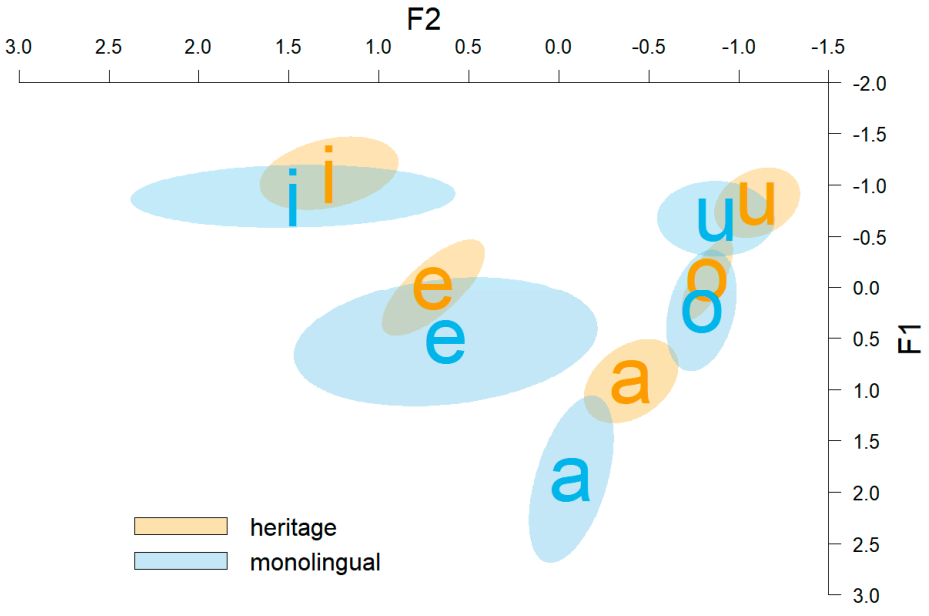

Figure 4. F1 × F2 (normalized) of Greek vowels produced by HSs and monolingual speakers.

Table 3. Results of Bayesian hypothesis testing. The hypothesis tested whether heritage < monolingual in terms of acoustic values for each Greek vowel.

Feature	Vowel	*β*	*SE*	*l—95% CI*	*u—95% CI*	ER	PP
F1	i	0.22	0.19	−0.10	0.54	6.89	0.87
	e	0.52	0.20	0.21	0.84	189.48	0.99
	a	0.95	0.20	0.62	1.27	Inf	1.00
	o	0.30	0.20	−0.02	0.62	15.74	0.94
	u	0.15	0.20	−0.18	0.48	3.63	0.78
F2	i	0.21	0.15	−0.03	0.46	12.61	0.93
	e	−0.06	0.15	−0.31	0.18	0.48	0.33
	a	0.33	0.15	0.08	0.57	75.92	0.99
	o	0.03	0.15	−0.21	0.28	1.46	0.59
	u	0.23	0.15	−0.01	0.48	17.10	0.94
F3	i	0.41	0.40	−0.25	1.04	5.64	0.85
	e	0.22	0.40	−0.45	0.87	2.39	0.70
	a	0.50	0.39	−0.15	1.13	8.78	0.90
	o	0.87	0.40	0.21	1.52	55.34	0.98
	u	0.67	0.40	0.02	1.33	21.86	0.96
Duration	i	0.03	0.01	0.01	0.05	101.56	0.99
	e	0.04	0.01	0.02	0.06	332.33	1.00
	a	0.04	0.01	0.02	0.06	570.43	1.00
	o	0.04	0.01	0.02	0.06	570.43	1.00
	u	0.02	0.01	0.00	0.04	15.33	0.94

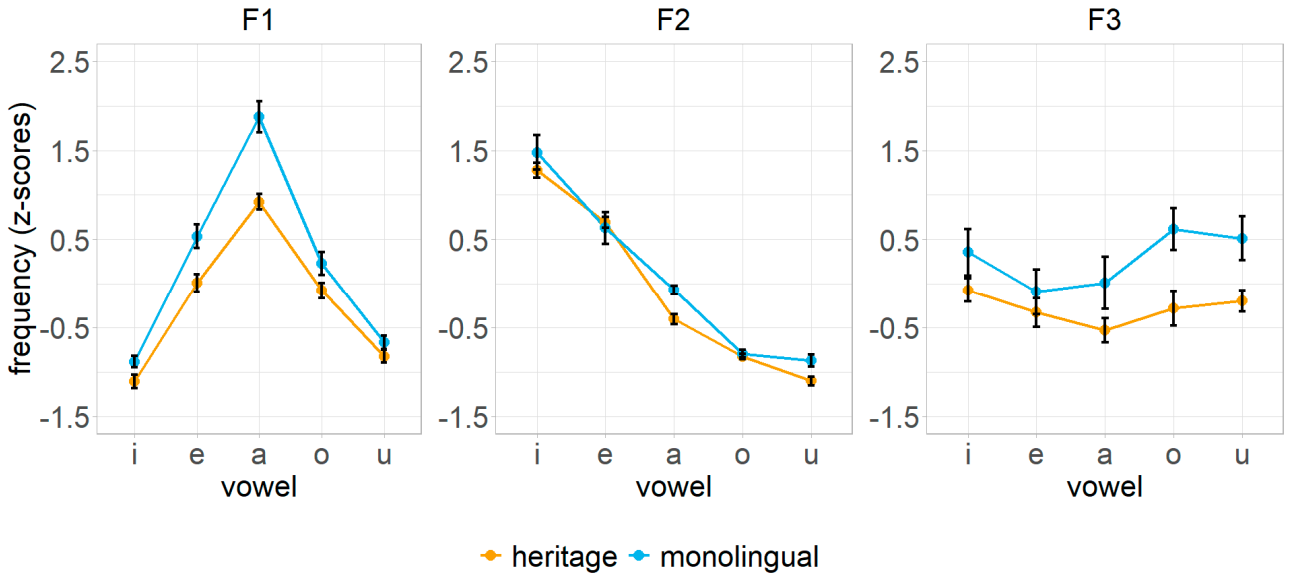

Figure 5. Formant frequencies (normalized) and *SE* of Greek vowels produced by HSs and monolingual speakers.

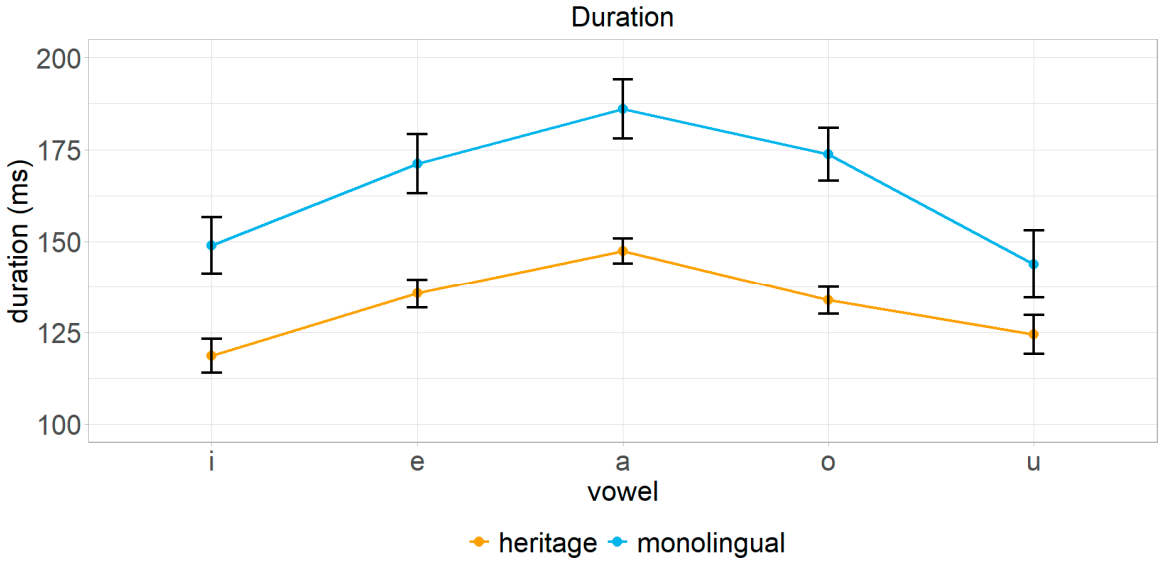

Figure 6. Duration (in ms) and *SE* of Greek vowels produced by HSs and monolingual speakers.

5. Discussion

This study examined the acoustic characteristics of Greek vowels (F1, F2, F3, and duration) produced by second-generation HSs of Albanian(Albanian-Greek bilinguals), and monolingual Greek speakers. We were interested in investigating the phonetic categories in the vowel space of bilinguals and monolinguals and explaining the source of potential differences between the two populations. The statistical analysis was conducted using Bayesian regression models. We employed for the first time an acoustic framework to study Albanian and Greek.

A crucial question was addressed regarding potential acoustic differences in the production of Greek vowels between HSs and monolingual speakers. Although HSs maintained clear boundaries between the different Greek vowel categories as seen in their productions, some acoustic aspects differed from those of monolingual Greek speakers. Specifically, vowels /e a o/ were produced with lower F1 values by HSs. Similarly, vowels /i a u/ were produced with lower F2 values, and vowels /o u/ were produced with lower F3 values. All vowels produced by HSs exhibited shorter durations compared to those of monolingual speakers. This shows that each Greek vowel was produced with at least two different acoustic features.

Another aim of this study was to identify the source of acoustic differences between HSs and monolingual speakers in their Greek performance. The lower F2 values of Greek /a u/ in HSs compared to monolingual speakers can be regarded as a crosslinguistic influence since Albanian /a u/ are further back than their Greek counterparts. In terms of F3, HSs appeared to have transferred phonetic patterns from their HL, resulting in lower values for Greek /o u/. Notably, this is consistent with the lower F3 values found in Albanian /o u/ compared to their Greek counterparts. Furthermore, the production of Greek vowels with a shorter duration by HSs can be explained as a crosslinguistic influence from Albanian, as Albanian vowels do have considerably shorter durations than Greek vowels.

These findings not only validate most of our initial predictions but also align with the notion that crosslinguistic influence operates from the nondominant language to the dominant language (see also [26,27]). In our study, the speakers' HL, which is not the dominant language of the society in which they reside and not the primary language in their everyday lives (albeit one of their L1s), was found to influence certain acoustic features of their dominant language based on the acoustic analysis of vowels produced by Albanian native speakers. Similar effects have been observed in previous studies. For instance, Natvik [38] concluded that English /o/ found in the speech of Norwegian HSs, who reside in the Upper Midwest region of the USA, originates from the Scandinavian long [o:]. According to Flege [23], crosslinguistic effects arise from the coexistence of the two languages within a common phonological space. Bilingual speakers strive to maintain auditory contrast between their L1 and L2 vowels and, consequently, their productions may differ from those of monolinguals of a given language. In our study, despite Albanian HSs also being L1 speakers of Greek, their vowel categories did not completely overlap with those of monolingual Greek speakers in some acoustic features.

This aligns with Flege's [23] hypothesis regarding deflected phonetic categories for bilinguals, which therefore extends to the context of simultaneous/early (heritage) bilingualism.

Nevertheless, not all observed phonetic productions can be attributed to crosslinguistic influence. In particular, the lower F1 values of Greek /e a o/ and the lower F2 values of Greek /i/ in HSs do not seem to simply result from crosslinguistic effects. This is because the acoustically similar Albanian /e a o/ exhibit comparable values to Greek /e a o/. In addition, Albanian /i/ demonstrates higher F2 values than its Greek counterpart. These findings align with Flege's [23] hypothesis that bilinguals develop deflected categories that do not solely reflect crosslinguistic influence since bilinguals' representations are based on different features or feature weights as compared to those of monolinguals. This divergence may stem from the fact that HSs exploit phonetic features not present in their nondominant HL. These features may possibly originate from the speakers' sociophonetic context, encompassing phonetic features common in their social environment. One possibility is that HSs acquire both their languages through input provided to a large extent by their parents and relatives who are first-generation immigrants with L1 Albanian and L2 Greek. The parental/environmental input may exhibit divergence from monolingual norms in both Greek and Albanian: in Greek due to late L2 acquisition and in Albanian due to L1 attrition. Thus, the abovementioned differences attested in the phonetic productions of HSs may potentially result from differential input (see, e.g., [74]). Such a possibility requires additional investigation examining the performance of the parental generation, a research direction that we aim to address in future work. An alternative explanation may be related to language-internal evolution phenomena of variation and variability, an approach which points to distinguishing variation from deviation [75]. Regarding the latter account, the adoption of these features by HSs may arise from the potential for language change. This phenomenon can impact not only vocabulary and grammar but also phonetic patterns, as speakers adjust to the linguistic features of their contact languages, as suggested by Natvik [38]. Considering the relatively long-term contact between Albanian and Greek speakers in a bilingual community, it is plausible that language contact over time is leading to the emergence of new phonetic features among Albanian HSs in Greece. While challenging to test within the scope of this study, this hypothesis presents an intriguing avenue for future research.

6. Conclusions

This study compared the acoustic characteristics of Greek vowels as produced by groups of adult Greek-speaking HSs of Albanian and monolingual Greek speakers, both residing in Greece. Some acoustic aspects were found to be different between the two populations as a result of crosslinguistic influence and the potential effect of sociophonetic factors. Future studies can investigate to a greater extent the sociolinguistic background of the speakers to gain deeper insights into the source(s) of phonetic differences and compare vowel production between Greek speakers and other HL populations such as first-generation immigrants. They can also assess the role of individual variation among participants in their productions. The findings of this study shed light on the complex interplay between HL acquisition and dominant language proficiency among Albanian-Greek bilinguals, contributing to our understanding of bilingual speakers' phonetic patterns in situations of intense language contact.

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