

Monolingualism vs. bilingualism: Formants as a personal identification of Slovenian and Italian vowels – absolute values versus ratios

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Zaradi govorcev, ki se razlikujejo po starosti, spolu, čustvih, telesni konstituciji itn., so absolutne vrednosti formantov različne. Ob primerjanju razmerij med formanti lahko ugotovimo, da so vrednosti razmerij med formanti veliko bolj stabilne in primerljive kot absolutne vrednosti. V prispevku sva analizirali razmerja med formanti F1, F2 in F3 na podlagi objavljenih meritev formantov za slovenski in italijanski jezik ter ugotavljali, ali so razmerja konstantna ne glede na absolutno vrednost posameznih formantov. Primerjati sva želeli italijansko in slovensko formantno razmerje pri eno- in dvojezičnih govornikih. Rezultati so med drugim pokazali, da opisne statistične mere za naglašene samoglasnike pri italijansko-slovenskih enojezičnih govornikih kažejo zmanjšanje srednje vrednosti F2/F1 od prednjih proti zadnjim samoglasnikom, z minimalno vrednostjo količnika/razmerja pri osrednjih in zadnjih samoglasnikih.

Since the speakers in this research differ in age, gender, emotions, physical condition, etc., the absolute values of the formants are different. Comparing the ratios between the formants shows that the values of the ratios between the formants are much more stable and comparable than the absolute values. The present paper analyses the relationships between formants F1, F2 and F3 on the basis of published formant measurements for Slovene and Italian and determines whether the relationships are constant regardless of the absolute values of the individual formants. The aim of the study was to compare the Italian and Slovenian formant relationships in monolingual and bilingual speakers. The results show, among other things, that descriptive statistical measures for stressed vowels in monolingual Italian-Slovenian speakers dis-

play a decrease in the mean value of F2/F1 from front to back vowels, with a minimum value for central and back vowels.

Ključne besede: enojezični in večjezični govorniki, formanti, slovenščina, italijanščina, razmerja med formanti, samoglasniki

Key words: monolingual and multilingual speakers, formants, Slovenian, Italian, relationships between formants' ratio, vowels

1 Introduction

Formants are the sound of the vocal folds filtered through the speech organs. They differ according to the structure and morphological characteristics of the speech organs, and primarily according to articulation during the production of vowels and sonorants. Ladefoged and Johnson (2010: 23) distinguish between the first formant, the one with the lower pitch (distinguishable in creaky voice) and the second formant, the higher one (which can be heard when whispering).

Among vowels, formants primarily reflect the mouth and pharynx, i.e., the position of the tongue in the oral cavity: oral formants reflect the mouth and nasal cavity, while pharyngeal formants reflect the pharynx (Vujnović 1990: 21). The oral formant (F2) is lowered from /i/ to /u/, while the pharyngeal formant (F1) is raised from /i/ to /a/ and then lowered from /a/ to /u/. These formant areas depend more on the characteristics of the vowels than on the characteristics of the speaker (Vujnović 1990: 21).

The basic formant areas are acoustically divided into three parts: the first formant is in the range of 200–750 Hz, the second formant is in the range of 750–2200 Hz (or lower for back vowels), and the third, weaker formant is above 2200 Hz. The third formant is important because it indicates certain features of pronunciation (Fant 1968), but vowels are primarily distinguished by the first and second formants: the second formant is different for each vowel, while the first formant forms a pair (Schindler 1974) (/i-u, e-o, ε-ɔ/). The position and shape of the second formant (which changes greatly from vowel to vowel, but is very stable for a given vowel in both women and men) determines the characteristics of a vowel (Vujnović 1990: 22). It is important to emphasise that the second formant is not determined alone, but in conjunction with the first and third formants. Its behaviour in connection with the other formants must always be taken into account (Vujnović 1990: 22).

Furthermore, the distinction of vowels depends not only on the absolute frequency value of each formant, but also on the overall formant configuration (Magno Caldognetto 1986: 167). The distribution of formants for a particular vowel is always dependent on the layout of the basic tone and the formants of the same vowel, as well as on the other vowels in the phonetic system.

Vowel formants are highly variable depending on age, gender, health and other influencing factors (i.e. Tivadar 2019). Several authors have attempted to devise scales to compare different speakers, both for linguistic studies – comparative phonology and phonetics – and for atypical speech in speech and language pathology or disorders, such as Parkinson’s disease (Bang et al. 2013), apraxia of speech (Jacks et al. 2013), delayed phonological development (Pollock 2013) and deafness (Naderifar et al. 2017; Ozbič & Kogovšek 2010; Rahilly 2012), as well as for cross-linguistic studies of the vowel system (Papakyritsis & Granese 2012), socio-linguistic variations in vowels (Watt 2012), foreign accent syndrome (Laures-Gore et al. 2006; Perkins & Ryalls 2012), and for the phonological absolutisation and comparative description of languages (ratio of consonants to vowels: Port & Dalby 1982, three cortical spectral distances: Syrdal 1985; Syrdal & Gopal 1986), bilingualism and dialects (Skubic & Ozbič 2018).

DeJoy (2011) examined steady states of vowels in CVC syllables and connected speech and compared F3/F2 and F2/F1 ratios, comparing vowels in different consonant neighbourhoods and formant patterns with previously published data. Hilenbrand and Gayvert (1993) analysed the classification of vowels based on fundamental frequency and formant frequencies produced by different groups of speakers. In addition, Chandrashekar and Manjunatha (2017) analysed the variability of vowel tract shape based on the ratio of formant frequencies under different vowel conditions (normal, ice-cold and after five minutes) and found that the F2/F1, F3/F2 and F4/F3 ratios differ.

Disner (1980) pointed out that the aim of these models is generally (a) to maximise the differences between vowel categories and (b) to minimise the differences in the same vowel spoken by different speakers, especially the differences related to the variability of vowel tract length.

In addition, Harrington (2010) analysed some of the different techniques used to analyse formant frequencies and the way in which formants change over time. These include k-means clustering to assess the influence of context and some methods for automatically localising vowel targets using vowel formant data. The technique of k-means clustering can be applied to give an indication of whether variability is influenced by different types of context. As Harrington argues, in speaker-independent strategies, all of the information for normalisation should reside in the vowel itself. Earlier speaker-independent strategies utilised formant ratios.

These types of speaker-independent auditory transformations are based on the idea that two equivalent vowels, even if produced by different speakers, result in a similar pattern of movement along the basilar membrane, even if the actual position of the pattern varies. Since there is a direct correspondence between basilar membrane motion and the frequency of a sound on a scale, a transformation to an auditory scale such as the Bark scale (or the ERB scale – see e.g. Glasberg & Moore 1990) is usually the starting point for speaker-independent normalisation. Regardless of these normalisation issues, many

researchers transform formant values from Hertz to Bark before performing further analysis because it is assumed that an analogous translation occurs in the ear. Similar transformations have been carried out for the Italian language (Cosi et al. 1995).

Naderifar et al. (2019) investigated whether or not the use of various acoustic parameters (Formant Centralisation Ratio (FCR), Vowel Space Area (VSA), F2i/F2u ratio (second formant of /i, u/)) is suitable for characterising impairments in the articulation of vowels in the speech of hearing-impaired speakers. The study showed that the FCR was a more sensitive acoustic parameter than both the F2i/F2u ratio and the VSA for distinguishing the speech of the HL groups from that of the normal group. Therefore, FCR is considered an early objective measure of impaired articulation of vowels in hearing-impaired speakers.

2 Slovenian vowel system

There are several classifications for the Slovenian vowel system. Some authors take into account both the length and the accent of the phoneme (Toporišič 1978), while others take a more functional view, claiming that duration and accent (Srebot Rejec 1987; Petek et al. 1996; Tivadar 2010), and word position (Zemljak Jontes 2004) are linked: unstressed vowels are short (according to Zemljak Jontes (2004) vowels in pre-stressed position are shorter than vowels in post-stressed position), stressed vowels are long and ə is always short by nature.

Toporišič's classification divides Slovenian vowels into stressed long vowels (i, short e, long e, long o, short o, u), stressed short vowels (i, long e, a, long o, u, ə) and unstressed short vowels (i, long e, a, long o, u, ə) (Toporišič 1968: 65). A more recent classification comes from Srebot Rejec (1998), who asserts that numerous factors influence vowelism (inherent and external), so that Slovenian vowels are divided in a binary way: stressed vowels are long, unstressed vowels are short. In this respect, ə is inherently short, but the stressed ə is definitely longer than the unstressed ə (Srebot Rejec 1987: 55). As a rule, unstressed vowels are neutralised into less stressed/lower vowels /i, e, a, o, u/.

Petek et al. (1996: 136) confirmed the hypothesis about the relationship between the length and the stress of a vowel through their research in the field of acoustics and phonetics. The only exception, in their opinion, could be the stressed /a/, which can have a long and a short variant of the stressed phoneme. In recent years, research has discussed two different vowels in terms of quality or an additional vowel, i.e., the mid-low vowel /ʌ/ (Jurgec 2011). Jurgec states that Slovenian has nine vowels and not eight. For the purposes of the present article, we will use the categorisation /i, e, ε, ə, a, ɔ, o, u/ for stressed vowels and /i, E, a, O, u/ for unstressed vowels. Slovenian vowels (i, e, ε, a, ɔ, o, u, ə, non-stressed versions of i, e/ε→E, a, o/ɔ→O, u) can be classified (Srebot Rejec 1998; Stopar 2015) according to the highest point of the tongue, namely palatal/

front (i, e, ε) and velar/back (a, ɔ, o, u), or according to tongue height, high/low position, front/back position and the roundedness or openness of the lips.

Toporišič (1978: 139) classifies phonemes according to the criteria of compactness/non-compactness/difuseness/non-difuseness/acuteness/gravity. Acute phonemes are at the front, gravitational phonemes are at the back, diffuse phonemes are high and compact phonemes are low.

Vowels can also be distinguished based on distinctive features. Toporišič (1978: 123) lists Lenček's table with the distinguishing features of Slovenian vowels from 1966. This is followed by Srebot Rejec (1987: 53), who proposes a classification that takes into account four criteria (high, central, back, rounded).

In recent decades, linguists have analysed the formants of Slovenian in numerous publications (Toporišič 1968, 1971, 1978; Srebot Rejec 1987, 1988, 1998; Jurgec 2005a, 2005b, 2006a, 2006b, 2011; Tivadar 2004), while interest in formants has also been growing in the fields of acoustics, electrical engineering and language technologies (Mihelič et al. 2003), as well as in the rehabilitation of people with voice, speech and hearing disorders (Ozbič 2000; Hočevar Boltežar 2008). In addition, studies have been carried out on the Slovenian dialectal speech or on the characteristics of consonants in connection with the characteristics of vowels in different word positions (Koletnik in Zemljak Jontes 2024; Unuk 2003, 2022, 2023; project Mezzanine – Basic Research for the Development of Spoken Language Resources and Speech Technologies for the Slovenian Language, 2022-2025).

Lenček (1966) was one of the first to analyse formants in Slovenian (cited in Toporišič 1968: 122, Toporišič 1971: 41), but Lehiste (1961) defined the vowel even before him.

Toporišič (1971, 1978) separated stressed long vowels, stressed short vowels and unstressed vowels.

Based on the generally recognised difference between front and back vowels, we can determine a corresponding proximity of F2 and F3 for front vowels and a corresponding proximity of F1 and F2 for non-front vowels. The height of F3 and F4 does not seem to be relevant in itself, but there is a recognisable gradient in F3 from long /o/ to stressed /u/ and in F4 from stressed /a/ to stressed /u/. (Toporišič 1971: 40).

Later, Petek et al. (1996) analysed formants with newer technology and provided values for F1, F2 and F3. This was followed by Ozbič (1997), who gave a comparative description of the Slovenian vowel system of monolingual Slovenian women from Slovenia and bilingual Slovenian women (Italian and Slovenian) from Trieste, as well as later measurements for hearing children and adolescents, and those who are deaf and hard of hearing (Ozbič 2000; Ozbič et al. 2010). Tivadar (2004: 42) analysed F1 and F2 in men and women. One year later, Jurgec (2005a) published new values for F1, F2 and F3, split in terms of proparoxytone, paroxytone and oxytone, and then values for F1, F2, F3 and F4 for acute, circumflexed and short stressed vowels (2005b), followed by values for tonemic and non-tonemic speakers in terms of tonemic stress

(Jurgec 2006a). In addition, Jurgec (2006b) listed the values of formants F1, F2, F3 and F4 for unstressed vowels, which are subdivided into pre-stressed and post-stressed vowels. The variability of the formant values between the aforementioned authors is expected, as these values vary according to gender, age, position in the word, syllable accent, etc.

Fant (1968), too, points out the importance of formants, especially their relationships in determining vowel articulation. A low F1 indicates a narrow oral cavity, so that the front and back vowels have a low F1 and the central vowels have a higher F1 (cf. the F1/F0 ratio). If the difference between F2 and F1 (F2/F1 ratio) is very large, this means that the tongue has advanced into the pre-palatal region (phonemes: stressed *i*, unstressed *i*, short *e*, middle *e*). If the difference between F2 and F1 is small and F1 is high, the tongue has moved backwards (for long *e*, *a* and long *o*, both conditions are fulfilled, while for non-front vowels only the first condition is fulfilled). If F2 is high and F3 is very high (F3/F2 ratio), the tongue is in the medio palatal position. This means that the F1/F0, F2/F1 and F3/F2 ratios are important for vowels, probably representing the high-low axis, the position of articulation in the oral cavity in two dimensions, the front-back axis.

3 Italian vowel system

Typically, Italian is described as a language with seven vowels: /i/, /e/, /ɛ/, /u/, /o/, /ɔ/, and /a/. Some speakers do not distinguish between the “open” and “closed” version of the vowels, or /e/ and /ɛ/, and /o/ and /ɔ/ (Krämer 2009; Berce 1986). Three of these are front, unrounded vowels, and three are back, rounded vowels. The low vowel, /a/, is neither front nor back. The two high vowels, /i/ and /u/, are always tense, while the low vowel is always lax. The middle vowels can be tense (also called closed) or lax (also known as open). Everything considered, the Italian vowel system is uncontroversial, with the exception of the distinction or lack of distinction between the open and closed versions of the middle vowels. However, it is generally recognised that the status of this distinction varies greatly between the different regions and varieties of Italian (Krämer 2009). The Italian vowel formants have been described by several authors: Ferrero et al. (1978), Ferrero (1972, 1984, 1994), Antonetti and Rossi (1970), Schindler (1974), Gaspari and Tirondola (1976), Zmarich and Bonifacio (2003), Bertinetto and Loporcaro (2005).

In Italian, there are opening and closing diphthongs (Bertinetto & Loporcaro 2005), depending on the position of the glide before or after the peak of the syllable. The diphthongs consist of two vowels within one syllable. The first or second vowel in the pair is always /i/ or /u/. Some common diphthongs are /ja, ɥa, ie, io, oi, ai, ej, ue, ou, iu/ and /uj/. Both vowels of the pair usually retain their individual sound properties, although one of the vowels usually functions as a semivowel or glide (Krämer 2009). After the syllabic peak, the vowel

becomes unstressed; before the peak, the vowel is lowered, i.e., [i→j, u→w] (Bertinetto & Loporcaro 2005). The set of Italian diphthongs is as follows: [je, jɛ, ja, jo, jɔ, ju], [wi, we, wɛ, wa, wɔ, wo], [eɪ, ɛɪ, aɪ, ɔɪ, oɪ, uɪ], [eʊ, ɛʊ, aʊ]. Triphthongs also occur in Italian, as in [ɡʊaɪ, aɪuɔla], arising from a sequence of two onglides, which are normally separated by a morpheme boundary plus a vowel (Bertinetto & Loporcaro 2005).

A comparison of the Italian and Slovenian vowel systems shows some similarities, namely 1) both have considerable variability between dialects; and 2) the vowel systems are similar with the exception of the semivowel in Slovenian. The differences are: 1) both have diphthongs: in Slovenian, the diphthongs are essentially a consequence of conjugation (3rd person singular, masculine) or declension of adjectives (1st person, masculine, nominative, accusative, etc.), and they occur at the end of the word, in the coda, whereas, in Italian, the diphthongs are word nuclei and independent of inflexion; 2) the Italian language has triphthongs; 3) vowels in Slovenian occur more frequently in nuclei or codae, whereas it is very common in Italian to have open syllables.

4 Research

4.1 Aim

The main aim of the present study was to analyse the ratios between the F1, F2 and F3 formants on the basis of published formant measurements for Slovenian and Italian, and to determine whether the ratios are constant regardless of the absolute frequency of the individual formants. Italian and Slovenian formant ratios were compared for monolingual and bilingual speakers.

4.2 Hypotheses

H1: The ratios between the vowel formants F1, F2 and F3 are constant and comparable between speakers and languages.

H2: Bilingual speakers have a unique vowel system and similar formant ratios, regardless of the language used.

4.3 Method

The research started with a meta-study of published scientific articles and books in the field of formants by Slovenian and Italian speakers. Electronic databases, such as PubMed, ERIC, Cochrane Library, COBISS, dLib, OPAC SBN... were searched for studies on formant values in Italian and Slovenian for monolingual

speakers, and for bilingual Slovenian-Italian speakers. In addition, databases of relevant libraries on phonology were consulted. After analysing the relevant literature, the present study incorporated research articles and descriptive articles and chapters in which measurements of F1, F2 and F3 were made and in which standard speakers (monolingual or bilingual) were studied.

Using descriptive analysis (number, mean, standard deviation, range, minimum, maximum), values of formant ratios for Slovenian and Italian vowels are presented.

Table 1: Description of the participants for Slovenian and Italian speakers

AUTHOR	YEAR	DESCRIPTION OF PARTICIPANTS
Slovenian		
Toporišič	1978	7 speakers of Slovenian, male, aged 22–45, $M = 31.0$. Educational level: university or higher. Slovenian as the dominant language, without dialectal influences, without speech and voice disorders.
Ozbič	2000	46 speakers of Slovenian, 29 male, 17 female, aged 5–45 years, $M = 13.98$, $SD = 12.24$. Slovenian as the dominant language (4 were bilingual): 14 adults, 32 children (predominantly 5–8-year-olds). 12 women and 2 men among the 14 adults, and 27 boys and 5 girls among the children. From different Slovenian regions, no professional speakers, without speech disorders. Dialect influence minimal or non-existent.
	(2010 et al.)	11 Slovenian children, aged 5–9 years, $M = 7.0$, $SD = 1.18$. 7 boys, 4 girls. Without any developmental diseases or disorders.
Petek et al.	1996	Petek et al. 1996: 2 male and 2 female standard speakers. Age unknown.
Tivadar	2004	6 Slovenian professional speakers on the national radio (Radio Slovenija), without speech disorders, from different Slovenian regions, without dialectal influences, trained for professional language use, employed in the Slovenian capital Ljubljana (central region): 3 women, 3 men aged 28, 33 and 38 years ($M = 33.0$), where the dominant language was Slovenian. Educational level: university.
	2010	7, Slovenian-speaking participants (the dominant language was Slovenian): 3 men, 4 women aged 29 to 53 years, professional speakers on the national radio (Radio Slovenija), without speech disorders, from different Slovenian regions, without dialectal influences, trained for professional language use, employed in the Slovenian capital Ljubljana (central region). Educational level: university. The audio material came from radio and television programmes (5 for television and 6 for radio). The speakers were Slovenian-speaking.

AUTHOR	YEAR	DESCRIPTION OF PARTICIPANTS
Jurģec	2005a	10 speakers (5 men, 5 women), living in the capital of Slovenia, the central region of Slovenia.
	2005b	10 Slovenian-speaking participants: 5 men (aged 35–63 years, $M = 38.6$), 5 women (aged 24–56 years, $M = 31.2$), living in the capital of Slovenia, the central region of Slovenia, $M = 35$ years.
	2006a	10 Slovenian native speakers (5 women and 5 men), $M = 35$ years, mainly from central Slovenia.
	2006b	10 Slovenian-speaking participants: 5 men (aged 35–63 years, $M = 38.6$), 5 women (aged 24–56 years, $M = 31.2$), living in the capital of Slovenia, the central region of Slovenia, $M = 35$ years.
Italian		
Ferrero	1972	25 females, 25 males, $N = 50$, different regions: Veneto, Piemonte, Lazio without dialectal differences
	1978	Male students, $N = 10$, central Italy (Florence)
	1984	Data from 1968: female, male and male children
	1994	($N = 25$)
Bertinetto, Loporcaro	2005	(Ferrero 1972; Ferrero et al. 1978) adults and children
Antonetti, Rossi	1970	
Bonazzi, Schindler	1973	
Gaspari	1976	Adults (female and male), children
Zmarich, Bonifacio	2003	4 children (1 year)
Italian and Slovenian		
Ozbič	1997	26 speakers of Slovenian, female, aged 18–30 years, $M = 24.0$. Educational level: university or higher. Slovenian as the dominant language, without explicit dialectal influence, from different Slovenian regions, no professional speakers, without speech disorders.
Ozbič	1998	15 were bilingual Slovenian-Italian, $M = 24.2$. 11 were monolingual Slovenian, $M = 23.5$.
Grošelj	2013	Unuk, 2003, Jurģec, 2005 for Slovenian; Sorianello, 2001, Calamai, 2002 for Italian (adult male speakers).
Skubic, Ozbič	2018	15 adult bilingual female speakers aged 20–28 years and 11 adult monolingual Slovenian speakers aged 21–30 years.

4.3.1 Variables

Absolute values of the formants F1, F2, F3, F4 and ratios between the frequencies of the formants F2/F1, F3/F2 and F4/F3 of the listed Slovenian and Italian vowels in monolingual and Slovenian-Italian bilingual speakers were the variables..

5 Results and discussion

In order to define the vowel systems in both languages, the two systems are described in monolingual speakers, followed by a comparative analysis between monolingual and bilingual speakers.

The descriptive statistical measures for stressed vowels (Table 2) in Italian and Slovenian monolingual speakers show a decrease in the F2/F1 mean from front to back vowels, with a minimum for central and central back vowels. The discrepancies between the maximum and minimum values are smaller for low front and central vowels. The differences between the minimum and maximum values are smaller for lax vowels and larger for tense vowels, and the variability is greater for high vowels than for low vowels. The ratios between F3 and F2 are decidedly smaller than the ratios between F2 and F1, especially for front vowels (less than 2), and larger for back vowels (more than 2). The smallest differences (all less than 1) between the lowest and highest formant ratio values are observed for front vowels. The mean values of the formant ratio are higher for back vowels than for front vowels. The differences between the minimum and maximum values are smaller for lax vowels and larger for tense vowels, and the variability is greater for back vowels than for front vowels.

Analysing the values of unstressed vowels and comparing them to those of stressed vowels, it can be established that the ratios are similar, but the values are usually lower due to the lower relative strength, duration, height and stress compared to stressed vowels. Namely, they are subject to the rule that the values for F2/F1 fall from the front to the centre and rise from the centre to the back, while the trend for the F3/F2 ratio falls from back to front. There is no obvious homogeneity in these values, but there are recognisable rules for the size of the ratios. The differences between the minimum and maximum values for F2/F1 for unstressed vowels are smaller for lax vowels and larger for tense vowels, and the variability is greater for front vowels than for back vowels.

In the values of the F3/F2 ratio, the differences between the minimum and maximum values are smaller for the front and central vowels and greater for the high back vowels, and the variability is greater for the high front and medial and high back vowels. The mean values of the F3/F2 ratio fall from front to back vowels. In particular, the material shows a high degree of consistency between the values and non-homogeneity in the case of an intentional pattern of speakers.

Table 2: Descriptive statistics of F2/F1 and F3/F2 ratios in monolingual speakers

F2/F1	Slovenian monolingual								Italian monolingual			
	Stressed				Unstressed							
	M	SD	Min	Max	M	SD	Min	Max	M	SD	Min	Max
i	7.4	1.54	5.5	10.7	6.5	1.19	5.4	8.0	8.0	1.78	5.8	10.8
e	5.6	.82	4.4	7.5					4.7	1.00	3.4	6.0
E (middle)									5.2	0.60	4.6	5.9
ɛ	3.3	.41	3.0	4.6	4.2	1.10	3.2	6.2	3.3	0.37	2.8	4.0
a	2.0	.53	1.7	3.6	2.4	.35	1.9	3.0	1.8	0.14	1.6	2.0
ɔ	2.0	.82	1.6	4.6	2.3	.33	1.8	2.8	1.8	0.30	1.6	2.5
O (middle)									1.9	0.06	1.8	1.9
o	2.4	1.39	1.8	6.4					2.1	0.32	1.7	2.6
u	2.9	1.71	1.8	8.3	2.6	.50	1.9	3.2	2.5	0.44	1.8	3.4
ɔ	3.0	.82	2.5	5.2	3.3	.21	3.2	3.5				
F3/F2												
i	1.3	.09	1.0	1.5	1.4	.16	1.2	1.6	1.3	0.05	1.3	1.4
e	1.3	.11	1.2	1.6					1.3	0.00	1.3	1.3
E (middle)									1.3	0.00	1.3	1.3
ɛ	1.4	.06	1.2	1.5	1.5	.08	1.4	1.6	1.3	0.00	1.3	1.3
a	1.9	.18	1.5	2.2	1.8	.11	1.7	1.9	1.8	0.04	1.7	1.8
ɔ	2.6	.18	2.2	2.8	2.8	.36	2.4	3.4	2.7	0.00	2.7	2.7
O (middle)									2.7	0.00	2.7	2.7
o	3.2	.27	2.5	3.5					2.8	0.00	2.8	2.8
u	3.0	.18	2.6	3.3	2.5	.39	1.9	3.0	3.1	0.34	2.8	3.3
ɔ	1.9	.16	1.6	2.1	1.8	.09	1.7	1.9				

Greater differences between the two languages can be observed in the F2/F1 ratio than in the F3/F2 ratio, and in the front high vowels than in the middle and back vowels. These differences may be due to morphological differences in the vocal folds, as well as vocal tract size and length, with males tending to produce lower formants than females and children due to their longer vocal tracts (Fitch & Giedd 1999).

5.1 Bilingual Italian-Slovenian speakers: Ratios of Slovenian and Italian formant values

In bilingual speakers, the similarities between the two languages are more frequent, especially with stressed vowels. To a certain extent, unstressed vowels vary more in value than stressed ones. The results show that the phonetic system of bilingual speakers is consistent: speakers use similar movement plans

for the same vowel in both languages, regardless of the verbal material. The phonological system, as a set of phonological categories, and the perception of vowels in each language seem to converge, more so for stressed than for unstressed vowels.

Table 3: Formant ratios of stressed vowels for bilingual speakers: Slovenian and Italian language

Language	Stressed vowels				Unstressed vowels			
	Italian		Slovenian		Italian		Slovenian	
	F2/F1	F3/F2	F2/F1	F3/F2	F2/F1	F3/F2	F2/F1	F3/F2
i	7.4	1.2	7.4	1.2	7.1	1.5	7.2	1.5
e	5.6	1.2	5.7	1.3	5.6	1.3	5.4	1.6
ɛ	2.7	1.5	2.7	1.5				
a	1.6	1.8	1.7	1.7	2.2	1.7	2.1	1.8
ɔ	1.7	2.4	1.8	2.4				
o	1.8	2.4	1.9	2.5	1.8	2.4	1.8	2.6
u	2.4	3.1	2.4	3.1	3.1	1.8	2.5	2.4

According to usage-based models of phonology, the more frequently a word is used and perceived in accented pronunciation variants, the more examples of accented tokens are memorised and then used for subsequent productions of that word. This can lead to greater production variability in speakers with more variable input than in speakers with less variable input (cf. Pierrehumbert 2001). In a recent study (Levy & Hanulíková 2019), 60 children in southern Germany (27 bilingual children with different language backgrounds, i.e., Russian, Turkish, Albanian, Serbian, Portuguese, Spanish, Greek, Ewe, Arabic, Urdu, Croatian, Italian, and 33 monolingual children) were tested on their production of eight German vowels. The results for vowel position (F1/F2) showed that greater experience with a regional variety or a foreign accent alone does not cause greater variability, but can lead to different vowel positions compared to speakers with less accent experience. Children with more experience with regional varieties (mostly Swabian) produced more closed and more frontal vowels, whereas children with more experience with foreign accents produced vowels with lower F1 values than children with less experience with foreign accents. Separate analyses for monolingual and bilingual children showed that more experience with regional varieties leads to different vowel positions in monolingual and bilingual children. While monolingual children show more closed and more frontal vowels (F1 values), which may be due to the influence of Swabian, bilingual children with greater input in a regional variety show higher F2 values.

6 Conclusion

The aim of this article was to present the acoustic characteristics of Slovenian and Italian vowels in monolingual and bilingual speakers, not in the traditional form of absolute values, but through F3/F2 and F2/F1 ratios. Due to the variability of the speakers (in terms of gender, age, dialect region and language) and the different vowel classifications for Slovenian and Italian vowels, the absolute formant values greatly differ among each other. This paper is an attempt to show more stable formant ratio values and provide a clearer picture of the vowel system. The ratio values make it possible to compare different speakers and different languages.

The analysis of the value ratios of most of the authors who have described formants confirms that the ratios between the horizontal and vertical axes or the mouth and pharynx are essential for the formation of vowel formants. However, there are additional variations, so this field requires further research.

Alongside the theoretical issues related to the phonetic system and classification, this article – as an overview article – is useful for all linguists dealing with speech production and analysis, speech synthesis in Slovenian, as well as rehabilitation, speech and language therapy, and clinical phonetics and linguistics. Formant values and their ratios can be useful indicators of vowel space, especially in populations with speech, phonation, resonance and breathing problems, such as hearing impairment and various neurogenic disorders, such as dysarthria and Parkinson's disease.

Further analyses and research in the Slovenian language, however, are needed, especially in the field of developmental phonetics and clinical phonetics.

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FORMANTI KOT OSEBNA IDENTIFIKACIJA SLOVENSKIH IN ITALIJANSKIH SAMOGLASNIKOV PRI ENO- IN DVOJEZIČNIH GOVORCIH – ABSOLUTNE VREDNOSTI PROTI RAZMERJEM

V prispevku sva analizirali razmerja med formanti F1, F2 in F3 na osnovi objavljenih meritev formantov za slovenščino in italijanščino. Želeli sva ugotoviti, ali so razmerja konstantna ne glede na absolutno pogostost posameznih formantov. Primerjali sva formantna razmerja pri slovenskih eno- in dvojezičnih ter italijanskih enojezičnih govoricah. Uporabili sva metodo metaštudije objavljenih znanstvenih člankov in knjig s področja formantov govorcev slovenščine in italijanščine. V elektronskih podatkovnih zbirkah, kot so npr. PubMed, ERIC, Cochrane Library, COBISS, dLib in OPAC SBN, sva raziskali študije o formantnih vrednostih v italijanščini in slovenščini za enojezične govorce in za dvojezične slovensko-italijanske govorce. V analizo relevantne literature sva zajeli znanstvene članke, v katerih so bile opisane opravljene meritve F1, F2 in F3, v raziskavo pa so bili vključeni standardni govorce (eno- ali dvojezični).

Rezultati so med drugim pokazali, da opisne statistične mere za naglašene samoglasnike pri italijansko-slovenskih enojezičnih govoricah kažejo zmanjšanje srednje vrednosti F2/F1 od prednjih proti zadnjim samoglasnikom, z minimalno vrednostjo količnika/razmerja pri osrednjih in zadnjih samoglasnikih. Analiza vrednostnih razmerij večine

avtorjev, ki so opisovali formante, potrjuje, da so razmerja med vodoravno in navpično osjo oziroma usti in žrelom bistvena za tvorbo samoglasniških formantov. Obstajajo pa dodatne različice interpretacije meritev, zato bi to področje zahtevalo nadaljnje raziskave. Članek je namenjen vsem, ki se ukvarjajo s produkcijo in analizo govora, sintezo govora v slovenščini, pa tudi z rehabilitacijo, logopedijo in jezikovno terapijo ter klinično fonetiko. Vrednosti formantov in njihova razmerja so lahko koristni indikatorji prostora samoglasnikov, zlasti pri populacijah s težavami pri govoru, fonaciji, resonanci in dihanju, okvarah sluha in različnih nevrogenih motnjah, kot sta dizartrija in Parkinsonova bolezen. Potrebne pa bi bile nadaljnje analize in raziskave slovenskega jezika, predvsem na področju razvojne in klinične fonetike.
