



Predicting Changes in L1 Vowels of Late Czech and Italian Bilinguals with French as L2

Marie Fongaro¹ , Barbara Gili Fivela² , Maud Péliissier³ ,
and Gabriel Hévr^{1,2,3}

¹ Institute of Romance Studies, University of South Bohemia in České Budějovice,
České Budějovice, Czech Republic

mfongaro@ff.jcu.cz

² CRIL – DREAM, University of Salento, Lecce, Italy

barbara.gilifivela@unisalento.it

³ ALTAE, Université Paris Cité, 75013 Paris, France

maud.pelissier@u-paris.fr

Abstract. This study examines whether vowels produced in the first language (L1, here Czech and Italian) by Czechs and Italians who moved to France as adults (i.e., late bilinguals, hereinafter Czech and Italian B) differ from those produced by Czech and Italian control speakers (hereinafter Czech and Italian C). Czech, Italian and French vowels differ in spectral characteristics, here examined by measuring the first and second formant (F1, F2). Consequently, L1 vowels of Czech and Italian B may ‘change’, that is, differ from those of Czech and Italian C since their second language (L2, here French) may influence their L1. We examined whether these changes in L1 vowels of Czech and Italian B could be predicted by a complex combination of non-linguistic factors relevant to late bilinguals. Significant results discussed in light of the Speech Learning Model and Attrition and Drift in Access, Production, and Perception Theory show that Italian B and C produce /i/, /ɔ/, /o/ and /u/ differently with respect to F1 and /e/ and /ɛ/ with respect to F2, and Czech B and C produce /a:/ and /ɪ/ differently in terms of F1. We propose a model incorporating a combination of non-linguistic factors which, out of the 20 models tested, predicted the best the occurrence of changes in L1 vowels of our late bilinguals; on the contrary, individual non-linguistic factors were not sufficient to predict them. Future research will confirm if this model may be generalised for reliable predictions of phonetic changes in the L1 of late bilinguals.

Keywords: L1 Changes · Vowels · Late bilinguals · Extralinguistic factors

1 Introduction

Previous research has examined at the phonetic level the first language (L1) of so-called ‘late bilinguals’, that is, adults who acquired their second language (L2)

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mostly during adolescence, and use it daily (for definition of late bilingualism, see [1]). Findings show that the L1 speech production of late bilinguals often (1) differs from that of L1 native speakers living in their L1 country, referred to as controls, and (2) is perceived as sounding less ‘native-like’ by L1 native listeners; in both cases, the cause of this is the influence of the late bilinguals’ L2 on their L1. Two terms are typically used to refer to this influence: L1 drift and L1 attrition. The former is commonly used to refer to L2 learners spending several weeks in an L2 country for intensive L2 lessons, and refers to changes in L1 speech that are temporary and attributable to a recent and short L2 experience. The latter commonly applies to late bilinguals who live in an L2 country for years, and is therefore defined as long-term changes in L1 speech attributable to the cumulative L2 experience. In this paper, both terms are of interest; we use the term ‘L1 changes’ to refer to both, at the phonetic level.

Authors agree that the occurrence of L1 changes in late bilinguals depends not only on dissimilarities in the phonetic systems of their L1 and L2, but also on many other non-linguistic factors (hereinafter extralinguistic factors) such as late bilinguals’ Length Of Residence/stay in L2 country (LOR), their Age of Arrival in that country (AoA), their L1 and L2 use and others, in which all late bilinguals usually differ. Despite previous research, deep understanding of the relationship between these extralinguistic factors and the occurrence of L1 changes is still lacking. This is mainly because (1) not all authors have examined this relationship in their studies, even though they collected data on late bilinguals that would have allowed it, and (2) when this relationship was examined, the results were inconsistent. The present study seeks to contribute to a better understanding of this relationship, investigating it in two groups of late bilinguals: late Czech-French and Salento Italian-French bilinguals (henceforth Czech B and Italian B, respectively). In particular, it examines whether L1 changes in their vowels may be predicted by a complex combination of extralinguistic factors. For this purpose, L1 speech production of Czech and Italian B is compared to that of Czech and Italian control speakers (hereinafter Czech and Italian C) who originate from the same geographical areas as the late bilinguals, more precisely Bohemia (Czech Republic) and Salento (Apulia, Italy), and have lived there for all or the majority of their lives. Czech and Italian B moved to France mostly as adults and lived there, in the Toulouse and Paris region, at the time of the study.

1.1 Why L1 Changes May Occur

The Speech Learning Model and its revised version (SLM and SLM-r, see, e.g., [2]) have been frequently used to predict the occurrence of L1 changes since they claim that late bilinguals’ L1 and L2 phonetic systems coexist in a shared phonetic space, causing L1 and L2 sounds to interact and to potentially influence each other. The occurrence of these interactions varies considerably from one late bilingual to another; among others, it depends on a wide range of endogenous factors related to individual late bilinguals, the degree of phonetic dissimilarity of an L2 sound from the closest L1 sound they perceive, or the quantity and

quality of L2 input they receive for the given L2 sound in ‘meaningful conversations’. Similarly, according to Attrition and Drift in Access, Production, and Perception Theory (ADAPPT, [3]), the occurrence of L1 changes depends on (1) similarity between L1 and L2 sounds and (2) other factors related to individual late bilinguals. ADAPPT also claims that the L1 of late bilinguals is ‘always’ impacted in ‘some way’ by L2 exposure and acquisition, and this impact concerns L1 sounds of late bilinguals that are similar to, but still noticeably different from, nearby sounds of their L2; it does not affect L1 sounds that strongly differ from their L2 sounds. It also claims that ‘we should look’ to extralinguistic factors to explain the differences in the extent of L1 changes among individual late bilinguals.

1.2 L1-L2 Combinations: Czech, Salento Italian and French

Czech (L1 of Czech B and C) and Salento Italian (L1 of Italian B and C) differ from French (L2 of Czech and Italian B) in monophthong oral vowels. Czech, here the variety of Czech spoken in Bohemia, includes five pairs of short and long vowels: /a/, /a:/, /ɛ/, /ɛ:/, /ɪ/, /i:/, /o/, /o:/, /u/, /u:/. Salento Italian, i.e., the Italian variety spoken in Salento, contains five vowels: /a/, /ɛ/, /i/, /ɔ/, /u/.¹ Thus, besides the length contrast in Czech, the two systems are quite similar. On the contrary, French comprises 12 oral vowels: /a/, /ɑ/, /e/, /ɛ/, /i/, /o/, /ɔ/, /u/, /y/, /ø/, /œ/, /ə/. Therefore, unlike in French, in Czech and Salento Italian, the vowels /y/, /ə/, /ø/, /œ/ as well as the phonological difference between /ɛ/ and /e/ and between /ɔ/ and /o/ do not exist (cf. [4,5]). This phonological difference however is more often realised in French by French people living in the Paris region, than by those living in the Toulouse region. Vowels /ɑ/ and /o:/ occur in only a few French and Czech words respectively. Hence, they are not considered in this study.

Some Czech, Salento Italian and French vowels are represented by the same IPA symbol (e.g., /a/), even if they slightly differ in their spectral characteristics across languages. To determine these differences, we plotted average values of the first and second formant (F1 and F2) of Czech, Salento Italian and French vowels into Fig. 1. Although Fig. 1 has several limits since it is based on the F1 and F2 of vowels measured in studies differing in methodology, it allows us to deduce that:

1. French /a/ has a lower F1 than both Czech /a:/ and Salento Italian /a/.
2. French /e/ has a lower F1 than Czech and Salento Italian e-sounds and it has a higher F2 than Czech e-sounds.
3. French /ɛ/ has a lower F2 than Salento Italian /ɛ/.
4. French /i/ has a higher F2 than Czech /i/ and a lower F2 than Czech /i:/ and Salento Italian /i/.

¹ The vowel system of ‘standard’ Italian, which is a reference variety spoken by professional speakers or speakers who attended public speaking courses, includes seven vowels: /a/, /ɛ/, /e/, /i/, /ɔ/, /o/ and /u/.

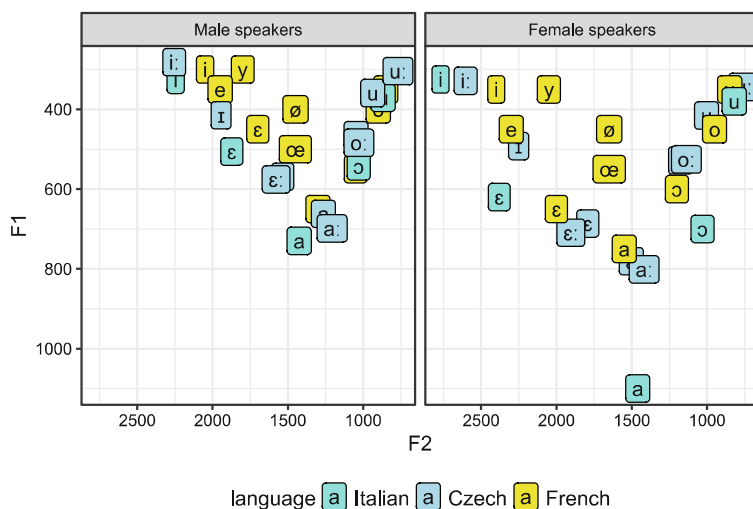


Fig. 1. Salento Italian, Czech and French vowels produced by male (left plot) and female (right plot) speakers. Source: [4–7].

5. French /ɔ/ has a higher F1 than Czech o-sounds, and French /o/ has a lower F1 than Czech and Salento Italian o-sounds.

Generally, the Salento Italian vowel space is less compressed than the Czech and French ones at the level of F1 and F2, and the Czech vowel space is slightly less compressed than the French one at the level of F2. Hence, Salento Italian vowels seem, on the whole, to differ more from French vowels than Czech vowels do.

1.3 Extralinguistic Factors and Studies on L1 Changes in Vowels

Extralinguistic factors may be defined as factors external to the language as a system, but related to the bilingual as a person (cf. [8–10]). [8] developed the ‘Sociolinguistic Questionnaire’ to collect data on these factors. This questionnaire collects (1) personal background data, such as, e.g., late bilinguals’ age, sex, LOR, AoA, education, and job, (2) data on their use of, proficiency in, and exposure to languages, and (3) data concerning their attitude towards L1 and L2 countries, culture, and mentality. Although its original version has many limits (cf. [10, 11]), several researchers have used it for their works (e.g., [12]), probably to follow the ‘tradition’ of its use in the field, while others modified it to overcome its limitations (e.g., [13]). Its limitations primarily lie in (1) reliance on self-evaluation and auto-declaration which may not reflect the reality, and (2) collection of more qualitative rather than quantitative data which are difficult to analyse statistically especially when the number of late bilinguals included in a study is low: Studies on L1 changes in vowels have most often included only about 10 late bilinguals, and rarely, up to 20 late bilinguals (see, e.g., [9] *vs* [14]).

Besides time and financial constraints of the research, this is usually due to the small number of late bilinguals with a given L1 living in a given L2 geographical area. This is also the case for our Czech B.

Excluding case studies and studies on late bilinguals staying in their L1 country or living only for a few weeks in the L2 country, to date, only [10, 12, 14–19] have examined L1 changes in the vowels of late bilinguals. Mostly, the authors focused on late bilinguals whose L1 or L2 was English and measured F1 and F2 values of all late bilinguals' L1 vowels. They used various production tasks to elicit L1 speech and different methods to normalize the formant values of L1 vowels. Interestingly, [10] found L1 changes to occur more in vowels produced by late bilinguals during free talk than when reading a text, and to vary in their amount depending on the method that was (not) used for formant values' normalization. In [16, 17], no L1 changes occurred in vowels of late bilinguals. They occurred in some, but not all, their vowels in [12, 14, 16]. In [15], the entire vowel space of late bilinguals' L1 'shifted' toward the vowel space of their L2 at the level of F1. The same occurred in [10] at the level of F2, whereas in [18], it shifted in the opposite direction at the level of F1, i.e., away from the L2 vowel space of late bilinguals.

The authors have also examined statistically the relationship between the occurrence of L1 changes and various extralinguistic factors, that is, LOR in [10, 12, 15, 17, 18], L2 proficiency in [10, 12, 18], L1 use in [10, 12, 16], factors linked to L2 learning in [17–19], preference for country, culture and mentality in [10], age, education in [12] and job in [18]. They did it mainly by (1) inserting these factors as independent variables into multiple linear regressions or as effects into Linear Mixed Effect models (LMEs), or by (2) dividing the late bilinguals into two groups based on their chosen extralinguistic factor and comparing L1 changes' occurrence between these two groups. In the case of (1), no significant result was found, whereas in the case of (2) more L1 changes occurred in the vowels of late bilinguals residing in an L2 country long-term than in those of students staying shortly in an L2 country in [15].

1.4 Goal and Hypotheses

This work aims to investigate the occurrence of L1 changes in the vowels of Czech and Italian B in relation to extralinguistic factors, by comparing their L1 speech to that of Italian and Czech C. It has the following three hypotheses (i.e., Hypothesis 1, 2 and 3):

1. In light of findings from previous studies, models on L2 sounds acquisition and differences between Czech, Salento Italian and French, both Czech and Italian B will produce their L1 vowels differently from the respective controls.
2. Given that the French vowel space differs more from the Italian than the Czech one, more L1 changes will occur in vowels of Italian B than in those of Czech B.
3. Since individual late bilinguals differ in terms of extralinguistic factors, they will differ in the extent to which L1 changes will occur in their vowels. Based

on results of previous studies, this variability cannot be predicted by individual extralinguistic factors, but by their complex combination.

2 Method

2.1 Speakers, Procedure and Material

For the purpose of the study, we recorded the L1 speech productions of 39 late bilinguals who lived in France for various amount of time: we had 17 Czech B speakers (O male, 17 females; *mean* age = 31.35 y.o.; *SD* = 8.96; *mean* LOR = 7.61 years; *min* = 0.17, *max* = 28.25) and 22 Italian B speakers (13 males, 9 females; *mean* age = 42.36 y.o.; *SD* = 11.53; *mean* LOR = 13.23 years; *min* = 1, *max* = 33). As regards controls, we had 17 Czech and 22 Italian C who matched the Czech and Italian B as closely as possible in age, sex and education level. The Czech and Italian B were born and/or grew up in Bohemia and Salento respectively, moved to France as adolescent/adults, and lived in the Toulouse and Paris region respectively. Czech and Italian C were born and/or grew up in Bohemia and Salento respectively and have lived there for all or most of their lives. All late bilinguals filled a short sociolinguistic questionnaire created by us. A few speakers declared the use of English at work or university. All speakers reported no speech disorder and received small monetary or material compensation for their participation.

The speech recording took place in quiet rooms in four different cities: (1) Toulouse, for Czech B, using a Neumann TLM 49 microphone and MOTU ULmk3 sound card; (2) Prague, for Czech C, using a head-mounted condenser microphone Bayerdynamic Opus 55 plugged directly into a pocket recorder set (see [20]), (3) Paris, for most of Italian B, using a Neumann KMS 105 microphone and Focusrite scarlett solo 3rd Gen USB sound card, (4) Lecce, for Italian C and few Italian B a few days after their arrival there for summer vacation (to avoid a long immersion in Salento Italian) using a Shure 86 microphone and Motu 828 MKII firewire sound card.

Czech B and C were asked to read a short text chosen from a book of a well-known Czech author which does not present any particular difficulty for reading and is commonly used for research on vowels by the Institute of Phonetics in Prague. For eliciting speech of Italian B and C, we created a set of pictures corresponding to Italian words with target vowels placed in stress-controlled position. The experimenter showed a flashcard with a picture illustrating the word on the PC screen and participants had to produce the word in the carrier sentence 'I say X'. Then, more flashcards were presented on the PC screen, and they had to describe the way the experimenter was moving the card, using the carrier sentence 'I put X next to Y. I moved X'. The words were easy to guess, and the pictures illustrating the most difficult words to guess were included in the training phase that took place before recording, so the speakers memorized their names. Italian B and C produced each target word a total of four times while Czech B and C produced it one or two times. In all, we had between three and fifteen words for each target vowel of each language.

2.2 Acoustic and Statistic Analysis

All recordings were orthographically transcribed: they were automatically labelled and segmented using BAS Web Services for the Italian recordings [21], and Prague Labeller for the Czech recordings [22]. The segmentation and labelling of all target vowels were hand-checked and adjusted where necessary in PRAAT [23]: The most common errors of labelling consisted in labelling Italian open mid vowels as close mid vowels and *vice versa*. Although there is no phonological difference between /ɛ/ and /e/ and between /ɔ/ and /o/ in Salento Italian, we labelled mid vowels in Italian words in accordance with their phonological transcription in widely recognised Italian dictionaries (e.g., [24]) that is, as /ɛ/, /e/, /ɔ/ and /o/ since we supposed that some Italian B may pronounce Italian /e/ more similar to the French /e/, rather than to the Salento Italian /ɛ/, due to the L2 influence on their L1. The automatic segmentation required manual correction in more than 40% of target vowels. We excluded from the analysis vowels that contained speech errors and pronunciation anomalies or were pronounced very quickly; the formant tracking in these vowels was not clear. In total, 14594 Italian and 3105 Czech vowels were analysed.

We automatically measured the F1 and F2 of the vowels using a PRAAT script by computing their average values from the middle third of the vowel duration. These values were inspected for outliers by vowel, formant values, and language. The spectrograms of outliers were hand-checked: If formant tracking was inaccurate, the default PRAAT parameters were adjusted to correct F1 and F2 tracking and new measurements were taken. We normalised these F1 and F2 values to reduce inter-speaker variation depending primarily on vocal tract size using Nearey 2 method [25] similarly to [18]. (Therefore, when we refer to F1 and F2 hereinafter, we are referring to their normalized values.) The Lobanov method [26] was not used since it likely eliminates legitimate linguistic variation from vowel data and frequently yields very noisy estimates of the vowel quality associated with individual tokens [27].

Statistical analyses ($\alpha = 0.05$, conf. interval = 95%) were performed in R [28] using packages *lmerTest* [29], *dplyr* [30], *rPraat* [31], *ggplot2* [30], *emmeans* [32] and in Python 3.11 using packages *pandas* [33], *numpy* [34], *statsmodels* [35] and libraries *matplotlib* [36], *seaborn* [37] and *sklearn* [38]. To test whether there is any difference between vowels produced by late bilinguals and controls (Hypothesis 1), we compared the speech production of Italian B to that of Italian C, and that of Czech B to that of Czech C by a set of LMEs, one for each formant and each vowel: We entered, as fixed effects, **group** (bilingual *vs* control speakers) and **language** (Czech *vs* Italian) with an interaction term (**language** was not entered if an analysed vowel exists in only one of the two languages). As for random intercepts, we included **speaker** and **word**. The random structure was kept maximal by including **group** as a by-word random slope, if it did not cause convergence issues. In the case of LMEs including **language** as fixed effect, *p*-values were obtained by performing pairwise post-hoc tests with the Tukey method.

To test whether L1 changes occur more in vowels produced by Italian B than in those produced by Czech B (Hypothesis 2), we computed for each late bilingual the total amount of L1 changes (hereinafter L1 CHANGES AMOUNT) by following four steps:

1. We calculated average values of F1 and F2 for each speaker for each vowel of each language.
2. We selected from these values those of controls, computed maximum and minimum per sex for each formant of each vowel of each language, and used the results as reference values: the minimum and maximum represent the limits of a range of how a single control speaker of a given sex and language can produce a given vowel on average.
3. We calculated Euclidean distances between the late bilinguals' and controls' vowels: If the values obtained in (1) for a given vowel of a given language produced by a specific late bilingual speaker of a given sex and language were included within the range of the minimum and maximum values calculated in (2) for a given vowel, language, and sex, the Euclidean distance was 0. Otherwise, the Euclidean distance was calculated as the distance between the values calculated in (1) for a given vowel of a given language produced by a specific late bilingual speaker of a given sex and the values calculated in (2) that were the closest to them, i.e., the maximum or minimum for a given vowel, language, and sex.
4. We calculated a sum of euclidean distances for L1 vowels for a specific late bilingual speaker.

We compared L1 CHANGES AMOUNT of Czech and Italian B by an independent two sample t-test (the difference in variances was checked by a F test).

As for Hypothesis 3, to test whether individual late bilinguals differ in the extent of L1 changes occurring in their vowels, we calculated a Coefficient of Variation (*CV*) of L1 CHANGES AMOUNT for all late bilinguals together and for the groups of Czech and Italian B separately. To examine whether this variability may be predicted based on a complex combination of extralinguistic factors rather than on single ones, using data collected on late bilinguals by the short questionnaire, we created the following eight extralinguistic variables:

1. *LOR* in years.
2. *AoA* (Age of Arrival).
3. *L2 use*: Average use of L2 (French) at home, work/university and during free time. We considered these three contexts to be of the same weight. Its high values mean automatically low L1 use.
4. *L2 level*: Higher values mean better proficiency in L2.
5. *L2 onset*: Values from 1 (corresponding to 'after university') to 5 (corresponding to 'elementary school') indicating when the start of L2 learning took place.
6. *L1 contact L2 country*: Contact with L1 by frequenting L1 native speakers living in the L2 country.
7. *L1 contact L1 country*: Contact with L1 through calls with L1 native speakers living in the L1 country.

8. *Time L1 country*: Number of days spend in L1 country over the past year.

We defined these variables as independent variables (**predictors**) and as a dependent variable (**target**) we had L1 CHANGES AMOUNT and used them for an exploratory analysis on all data (39 late bilinguals): In R, we inspected the relationship between each **predictor** and the **target** visualizing data in scatter-plots with Locally Estimated Scatter-plot Smoothing and calculating trace of smoother matrix by a set of local regression models. In Python, we generated a Pearson correlation matrix, calculated the Variance Inflation Factor (*VIF*) for all **predictors** in order to check for multicollinearity, tested whether the **target** may be predicted by all eight independent variables by fitting Ordinary Least Squares (OLS) Multiple Linear Regression and Elastic Net Regression that automatically selected from 36 predictors (8 main effects, 28 pairwise interactions), using Leave-One-Out Cross-Validation (LOOCV) to determine the regularization strength, with hyper-parameter tuning $\alpha = 100$ and L_1 ratio = 0.5 via cross-validation.

Results of this analysis suggested the relationship between **predictors** and **target** to be non-linear and complex, so we searched for meaningful combinations of the eight **predictors** and, guided by the results of exploratory analysis, we created three new independent variables (hereinafter ‘combined variables’):

1. *L1 contact* = normalised *L1 contact L2 country* + normalised *Time L1 country*. *L1 contact L1 country* was not considered as it correlated differently with L1 CHANGES AMOUNT across the groups of late bilinguals ($r = 0.2$ for Czech B, $r = -0.2$ for Italian B.)
2. *Comprehensive L2 use* = $(L2\ use \times LOR \times L2\ level)^2$. It describes L2 use in its complexity; the higher the *LOR*, the higher the cumulative L2 use is likely to be and the higher the *L2 level*, the higher the quality of L2 use is likely to be. A squared multiplicative term is motivated by the apparent exponential relationship between the sums and L1 CHANGES AMOUNT during visualization.
3. *L2 acquisition* = $(L2\ onset \times 1/AoA \times LOR)^2$. Squared for the same reason as above. Its higher values indicate early beginning of French learning, early arrival in France and longer full immersion in French by staying in France.

We tested whether the **target** may be predicted by these combined variables by running OLS Multiple Linear Regression and Elastic Net Regression, which automatically selected from 6 predictors (3 main, remaining interactions), using LOOCV to determine the regularization strength (hyper-parameter: $\alpha = 0.0043$ and L_1 ratio = 0.5). The results suggested the relationship between **target** and extralinguistic factors to be even more complex. Therefore, we searched for a more complex model that could well predict L1 AMOUNT CHANGES by dividing randomly late bilinguals’ data into two sets, a training set (70% of data; 12 Czech B, 15 Italian B) and test set (30% of data, 5 Czech B, 7 Italian B; test set was a part of exploration of data rather than external validation of the best model). We created 20 models that we thought could predict L1 AMOUNT CHANGES: To create these models, we used at least three and at most eleven of

the total of eleven independent variables and included them into models with and without interactions, ensuring that each model made sense. The best model was chosen from models exploration results as that with the highest value of R^2 , fitted on training set and evaluated on test set and all data (both sets together). Then, we tried a model selection on all data to see whether the result changed. We further verified the best model validity by running LOOCV, permutation tests (5000 permutations of the **target**, recording the best R^2 across all 1980 candidate models), Bootstrap stability with 2000 resamples and a repeated hold-out simulation (Monte Carlo cross-validation): 1000 random 75/25 splits ($n = 30$ train, $n = 9$ test), refitting on each training set and recording test-set R^2 . We emphasise that the three combined variables were created from the same data on which they were subsequently tested; they are therefore exploratory.

3 Results

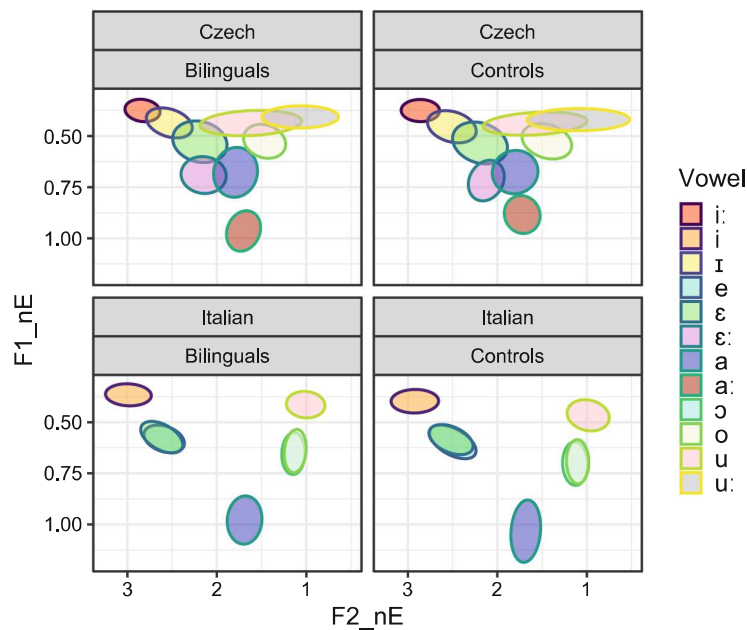


Fig. 2. Normalised F1 and F2 values of Czech (left panel) and Salento Italian (right panel) vowels produced by late Czech and Salento Italian-French bilinguals (solid line) and Czech and Italian controls (dashed line). The ellipses represent 68% of data.

Results of the set of LMEs show that Italian B significantly differ in their speech production from that of Italian C (1) as regards F1 of /i/ ($\chi^2(1) = 14.02$, $p = 0.0002$), /ɔ/ ($\chi^2(1) = 9.74$, $p = 0.0018$), /o/ ($t = -3.91$, $p = 0.0002$) and /u/

($t = -4.93$, $p < 0.0001$), and (2) as regards F2 of /e/ ($\chi^2(1) = 4.37$, $p = 0.0366$) and /ɛ/ ($t = 2.57$, $p = 0.0122$): F1 values of /i/, /ɔ/, /o/ and /u/ produced by Italian B are lower than those of these vowels produced by Italian C (β and SE as regards /i/: -0.02 , 0.01 ; /ɔ/: -0.04 , 0.01 ; /o/: -0.05 , 0.01 ; /u/: -0.05 , 0.01), and F2 values of their /ɛ/ and /e/ are higher than those of Italian C (β and SE as regards /ɛ/: 0.10 , 0.04 ; /e/: 0.06 , 0.03). Czech B significantly differ in their speech production from that of Czech C as regards F1 of /a:/ ($\chi^2(1) = 18.46$, $p < 0.0001$) and /ɪ/ ($\chi^2(1) = 5.25$, $p = 0.0219$); they produced /a:/ with higher F1 ($\beta = 0.06$, $SE = 0.01$) and /ɪ/ with lower F1 ($\beta = -0.01$, $SE = 0.01$) compared to Czech C. There were no other significant results. See Fig. 2 for illustration.

As regards the values of L1 CHANGES AMOUNT, (1) its variances between Czech B and Italian B, compared using the F-test, do not significantly differ ($F(16, 21) = 0.56$, $p = 0.24$), (2) its mean value is not significantly higher for Italian B than for Czech B (tested by one-tailed t-test: $t(37) = -1.14$, $p = 0.13$, *mean* L1 CHANGES AMOUNT for Czech B = 0.17 , *mean* L1 CHANGES AMOUNT for Italian B = 0.22), and (3) its values of Coefficient of Variation indicate high variability in Czech B ($CV = 74\%$), in Italian B ($CV = 75\%$) and in all late bilinguals, i.e., Czech and Italian B considered together ($CV = 76\%$).

Table 1. Pearson correlation matrix for eight independent variable and VIF. c.=country, cnt=contact, amt=amount.

	L1 changesamt	LOR	AoA	L2onset	L2 use	L2level	L1 cnt	L1 c.	L1 cnt	L2 c.	Time	L1 c.	VIF
L1 changes amt	1.00	0.25	0.08	0.01	0.07	0.22	0.03	0.01	-0.22	NA			
LOR	0.25	1.00	0.17	-0.43	0.10	0.43	-0.03	0.06	-0.36	4.34			
AoA	0.08	0.17	1.00	-0.14	-0.36	-0.15	0.14	0.18	-0.12	16.79			
L2 onset	0.01	-0.43	-0.14	1.00	0.21	-0.01	-0.19	0.23	-0.03	14.58			
L2 use	0.07	0.10	-0.36	0.21	1.00	0.52	-0.18	0.01	-0.20	21.10			
L2 level	0.22	0.43	-0.15	-0.01	0.52	1.00	-0.38	0.11	-0.60	34.23			
L1 cnt L1 c.	0.03	-0.03	0.14	-0.19	-0.18	-0.38	1.00	0.26	0.07	9.62			
L1 cnt L2 c.	0.01	0.06	0.18	0.23	0.01	0.11	0.26	1.00	-0.23	3.11			
Time L1 c.	-0.22	-0.36	-0.12	-0.03	-0.20	-0.60	0.07	-0.23	1.00	2.15			

Table 1 gives Pearson correlation coefficient for the eight independent variable and their VIF values. Results of OLS Multiple Linear Regression reveal that these variables do not significantly predict L1 CHANGES AMOUNT ($F(8, 30) = 0.53$, $p = 0.8220$, $R^2 = 0.125$), nor any of them separately ($p > 0.05$). The LOOCV Q^2 of -0.324 indicates that the model predicts new observations worse than the sample mean. As for Elastic Net Regression, the model fails to identify any **predictors** that meaningfully improve predictive accuracy beyond the baseline mean ($Q^2 = -0.08$). All feature coefficients are driven to zero, indicating that the independent variables do not possess discernible linear relationships with the outcome within this dataset.

As for the three combined variables, they yielded a marginal, non-significant OLS Multiple Linear Regression fit ($F(3, 35) = 2.87$, $p = 0.0504$, $R^2 = 0.20$).

Only *Comprehensive L2 use* was individually significant ($\beta = 3.126e - 07$, $SE = 1.13e - 07$, $t = 2.31$, $p = 0.0270$), but within a non-significant overall model and among tested combined variables, so this cannot be interpreted as a reliable effect. The LOOCV Q^2 of -0.022 indicates that the model predicts new observations worse than the sample mean. As for Elastic Net Regression, the model does not identify **predictors** that meaningfully improve predictive accuracy beyond the baseline mean ($Q^2 = -0.28$). Among the 20 candidate models, the best-fitting model is: '*L1 contact * L1 contact L2 country + L1 contact + L1 contact L2 country + Comprehensive L2 use + L2 acquisition*'; it reaches the highest in-sample R^2 of 0.47 on the training set ($F(5, 21) = 3.77$, $p = 0.0136$). Its held-out R^2 is 0.10 on the test set and its R^2 on all data is 0.41 ($F(5, 33) = 4.61$, $p = 0.0026$). This model results still achieves the best fitting when trying the model selection on all data (adj. $R^2 = 0.32$), and its LOOCV Q^2 of 0.223 indicates that it predicts new observations better than the sample mean. Validation, however, indicates the fit does not generalise. Because the model is selected from 1980 candidates after data-driven feature construction, the appropriate selection-corrected significance is $p = 0.188$ (permutation test), i.e., not significant once the search is accounted for. R^2 fall to 0.10 on the held-out test set. Across 1000 random 75/25 splits the median test R^2 was 0.13 ($mean = -0.04$), with R^2 0 only in 63% of splits: the model performed worse than the sample mean in over a third of splits. Bootstrap analysis showed the parameters kept their sign in $> 95\%$ of resamples ($P(\text{sign flip}) < 0.05$), except for *L1 contact* ($P(\text{sign flip}) = 0.28$).

4 Discussion and Conclusions

In this study, we investigated L1 changes in vowels of Czech and Italian B, by comparing their L1 speech production to that of Czech and Italian C, and whether the occurrence of these changes may be predicted by a complex combination of extralinguistic factors. We expected Czech and Italian B to produce their L1 vowels differently from respective controls (Hypothesis 1). We found that (1) Italian B and C produce /i/, /ɔ/, /o/ and /u/ differently with respect F1 and /e/ and /ɛ/ with respect F2, but similarly as concerns the other Italian vowels, and (2) Czech B and C produce /a:/ and /ɪ/ differently with respect to F1, but the other Czech vowels similarly. Hence, Hypothesis 1 was only partially confirmed: Czech and Italian B differed in their production from that of respective controls in some, but not all, their L1 vowels.

These findings are straightforward to interpret: We assume that, as the French vowel space is generally more compact compared to the Italian one, the L2 of Italian B caused the overall lowering of F1 in their vowels. More specifically, French /o/ has lower F1 compared to Salento Italian /ɔ/ (cf. Sect. 1) which we assume causes the low F1 of L1 /ɔ/ of Italian B. We believe the same happened as for their L1 /i/, /o/ and /u/, whose low F1 would be a result of an influence of French on the late bilinguals' L1. Similarly, French /i/ has a lower F1 compared to Czech /ɪ/ (cf. Section 1), which we believe led Czech B to produce their L1 /ɪ/ with lower F1 compared to Czech C, as a result of an influence of their L2 /i/

on their L1 /ɪ/. In the light of ADDAPT, this result also suggests that Czech B consider French /i/ and Czech /ɪ/ to be sufficiently similar sounds to allow the former to influence the latter. All these results are therefore consistent with the assumption of the SLM and SLM-r that, for bilinguals, the L1 and L2 sounds can interact and therefore influence one another.

We also expected the F1 of /a/ of Italian B to be lower than that of Italian C, as /a/ has a lower F1 in French than in Salento Italian. This was not confirmed. However, since the *p* value was 0.05, we assume that if more data were available, this could be confirmed. French /ɛ/ does not have a systemically lower F1 compared to Salento Italian /ɛ/ (cf. Sect. 1); we may argue that, for this reason, Italian B may assimilate French /ɛ/ to their L1 e-sounds as these two vowels have similar F1 values. The significant result regarding the F1 of the /a:/ of Czech B is more difficult to interpret: French /a/ has lower F1 than Czech /a:/, so we would expect Czech B to produce /a:/ with a lower F1 to ‘approach’ the values of French /a/. However, the opposite occurred. We speculate that Czech B produce /a:/ with a higher F1 compared to Czech C because they want to maintain a clear contrast between their L1 /a:/ and L2 /a/, which would lead them to overemphasize the characteristics of their L1 /a:/, consequently producing it with higher F1 values. This phenomenon may happen in the context of L1 attrition and is considered a ‘dissimilation effect’. In the light of ADDAPT, this also signifies that Czech B consider Czech /a:/ similar to French /a/, yet different enough that L2 may influence L1. As for F2, we assume that F2 of French /e/ is generally higher than that of Salento Italian e-sound, even if it is not always clear (cf. Sect. 1), and consequently believe that French /e/ would have an influence on /e/ and /ɛ/ of Italian B, causing an increase of their F2 value.

In Hypothesis 2, we predicted more L1 changes to occur in the production of Italian B than in that of Czech B. We found average of L1 CHANGES AMOUNT to be higher, but not significantly, for Italian B than for Czech B; therefore Hypothesis 2 was not confirmed. On the one hand, it can be assumed that this result suggests that Czech and Italian vowel systems do not differ enough for more L1 changes to occur in one group of late bilinguals than in the other. On the other hand, it is important to consider that our samples used in the t-test (17 Czech and 22 Italian B) are limited in number and a power analysis performed in R shows only 46% chance of detecting a true effect (54% probability of a Type II error). Therefore, this study merits to be enlarged by including new Italian and Czech B participants: while increasing the number of Italian B should be simple since thousands of Italians from Salento live in the Paris region, it might be not so easy for Czech B as only a few Czechs live in the Toulouse region.

In Hypothesis 3, we predicted that the amount of change in L1 vowels would differ between late bilinguals. Coefficients of Variation of L1 CHANGES AMOUNT indicating high variability in Czech B, in Italian B, as well as when all late bilinguals were considered together confirmed this. Interestingly, the variability was similarly higher for Czech B, Italian B and when all late bilinguals were considered together. This finding is consistent with the SLM-r and ADDAPT assump-

tion that the occurrence of L1 changes vary from one individual to another. We also expected that individual extralinguistic factors would not significantly predict the extent of L1 changes occurrence in the vowels of a late bilinguals. This was confirmed since it was not possible to predict L1 CHANGES AMOUNT neither by OLS Multiple Linear Regression with eight independent variable nor by Elastic Net Regression. Therefore, extralinguistic factors *LOR*, *AoA*, *L2 onset*, *L2 use*, *L2 level*, L1 contact with L1 native speakers living in L1 and L2 country and time spent in L1 country are insufficient to predict the occurrence of L1 changes when considered individually. This finding is consistent with the previous studies on L1 changes in vowels (see Sect. 1) in which no extralinguistic factor was found to predict L1 changes.

We expected a complex combination of these factors may predict the extent of occurrence of L1 changes, and this was only partially confirmed: we found new combinations of these factors and a model that, out of the 20 models tested, was the best candidate for predicting L1 AMOUNT CHANGES on our data. However, its corrected *p* value shows its limits: more data are needed to confirm the validity of this model and whether it can be generalised in the field of phonetic L1 attrition and drift. We invite researchers to deepen this point by testing the model on their data and by searching for a new combinations of extralinguistic factors. In particular, we think the *L1 contact* variable in our study might be improved by combining better extralinguistic factors and by collecting more quantitative data. Overall, our results suggest that the analysed extralinguistic factors have an impact on L1 changes, however to understand it precisely, more research is needed.

To conclude, this paper showed changes in some, but not all, L1 vowels of late Salento Italian-French and Czech-French bilinguals that were interpreted as an influence of their L2 on their L1. As in previous studies, it was not possible to predict these changes by individual extralinguistic factors. This paper brought a first examination of their prediction by a complex combination of these factors. More data are needed to confirm whether the model proposed here reliably predicts phonetic changes in L1 of late bilinguals.

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