FOREIGN LANGUAGE LEARNERS ACQUIRE L2 PHONETIC DETAIL: GOOSE AND FOOT FRONTING IN NON-NATIVE ENGLISH*

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Abstract
Whether late learners discern fine phonetic detail in second-language (L2) input, form new phonetic categories, and realize them accurately remains a relevant question in L2 phonology, especially for foreign-language (FL) learning characterized by limited exposure to interactional native input. Our study focuses on advanced Czech learners' production of the L2 English vowels GOOSE and FOOT. While English /u/ and /ʊ/ have been undergoing fronting, their Czech equivalents, /uː/ and /u/, are fully back. We show that although the spectral differentiation of /u/-/ʊ/ is smaller in the learners' than in native speech, the vowels being contrasted primarily in length, even FL learners can shift their L2 sound categories towards native-like targets, or in this case, produce English /u/-/ʊ/ as fronted.

Keywords: back-vowel fronting, fine phonetic detail, FOOT vowel, foreign language learning, GOOSE vowel, second language phonology

1. Introduction

The topic of this paper is the accuracy of vowel production in the speech of highly proficient and highly motivated learners of English as a foreign language (EFL). Specifically, the study examines pronunciation of English high back vowels /u/ and /ʊ/ by young Czech adults, trained to become English language professionals.

In trying to explain why late second language (L2) learners' pronunciation often falls short of the native speaker model, researchers have found the concept of equivalence classification very useful. Originally introduced by Flege as a part of his influential Speech Learning Model (SLM; Flege 1987, 1995), equivalence classification can be understood as a cognitive mechanism blocking the formation of a new L2 sound category. This happens when an L2 learner uses a single

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phonetic category to process L1 and L2 sounds that are perceptually linked for the learner. When two L2 sounds are not perceived as different, they come to resemble one another in the learners' production. SLM's equivalence classification is compatible with, though not identical to, the concept of category assimilation of an L2 contrast within the Perceptual Assimilation Model of L2 phonological learning (PAM-L2) formulated by Best and Tyler (2007) as an extension of Best's non-native speech perception model (Best 1995). In PAM-L2, linking of L1 and L2 sounds as equivalent takes place also at the phonological functional level, i.e. perceived L2 phones that are realizations of two distinct L2 phonemes may be both assimilated to one L1 phoneme. In this paper, we ask whether the accuracy of Czech EFL learners' production of English high back vowels can be both modulated by the phonological mapping of the English tense-lax contrast on the Czech long-short contrast and at the same time show evidence of a phonetic shift towards the acquisition target driven by the dissimilarity of the L1 and L2 phones.

The assumption that accuracy of L2-sound production is conditioned by accuracy of L2-sound perception is widely accepted (e.g. Flege 1995, Baker & Trofimovich 2006). It is also known that the initial perceptual flexibility evidenced in infants (Tees & Werker 1984), i.e. the sensitivity to phonetic details of all speech sounds whether native or non-native, declines with increasing native language experience (Kuhl et al. 2008). The more firmly established a speaker's L1 phonology is, the more likely they are to display equivalence classification when exposed to L2 sounds. Overcoming the constraints posed by the established native-language speech sound system is then a crucial problem for learning the phonology of a second language. It entails learning to respond to subtle acoustic-phonetic dissimilarities between L1 and L2 phones initially classified as phonologically equivalent. Much of the success of such learning depends on the quality and quantity of the input that learners receive (Flege 2009).

Empirical studies have supported the assumption made both in SLM (Flege 1995) and in PAM-L2 (Best & Tyler 2007) that over the course of learning even adult learners' representations of L2 sounds can be systematically shaped by subtle acoustic-phonetic information in the input. Thus, experienced learners perceive and produce L2 sounds more accurately than less experienced learners (e.g. Flege 1987; Flege, Takagi & Mann 1995; Flege, Bohn & Jang 1997). However, many of these studies test learners who acquire their L2 in naturalistic communicative settings, immersed in authentic L2 input, inundated with native exemplars of L2 phones while the exemplars of L1 phones are underrepresented or not encountered at all, depending on the amount of L1 use. In contrast to the L2-immersed individuals, learners who are not consistently exposed to L2 input in the ambient environment, such as instructed learners of a foreign language, may not show improvement over time (e.g. Bohn & Flege 1992).

Learners in the foreign language learning situation, specifically EFL learners, are the focus of the present study. In order for any L2 learner to develop sensitivity to acoustic properties of L2 sounds, to notice L2–L1 differences and refine their L2 sound categories, it seems necessary to be in frequent contact with a variety of speakers from the same dialect. However, EFL learner's exposure to authentic English used communicatively in a native English-speaking community is very sporadic. The native pronunciation models that learners do encounter interactively (e.g. native English teachers, personal acquaintances) and in media (via textbook recordings, YouTube, computer games, TV shows, etc.) may be too diverse to allow them to develop stable sound representations close to one specific native English variety. Instead, their representations of L2 sounds are mainly shaped by frequent exposure to foreign-accented exemplars produced by their non-native teachers and peers. In addition, since EFL learning occurs in a pervasive L1 environment, the daily use of the L1 relative to L2 is typically very high. The interconnectedness of the learner's L1 and L2 sound patterns (Flege, Frieda & Nozawa 1997; Guion, Flege & Loftin 2000) results in L2 sound representations being constantly shaped by L1 interference due to the overwhelming prevalence of daily L1 use.

2. High back vowels in Czech and English

The present study aims to examine the availability of subphonemic information to foreign language learners by exploiting a phonetic difference between English high back vowels and their closest equivalents in Czech, our learners' L1. Czech is a vowel-length language contrasting the monophthongs /iː, ɪ, ɛː, ɛ, aː, a, oː, o, uː, u/ (Šimáčková, Podlipský & Chládková 2012). Native Czechs are highly sensitive to vowel duration in speech even when listening to non-Czech vowels (Chládková, Escudero & Lipski 2013). Czech learners of English are biased to rely on duration at the expense of spectral information when differentiating vowels like English /ɛ/ and /æ/ (Šimáčková 2003) and tense /i/ and lax /ɪ/ (Podlipský 2004). It can be expected that the second-language contrast between /u/ and /ʊ/, represented by the keywords GOOSE and FOOT in Wells' lexical sets (Wells 1982), is also likely to be interpreted as a long-short contrast, with the GOOSE vowel categorized as equivalent to long Czech /uː/ and the FOOT vowel as equivalent to a short Czech /u/.

The English and Czech high back vowel pairs, /u/–/ʊ/ and /uː/–/u/, differ not only in the relative weight of duration vs. spectral quality as cues to the vowel contrasts, but also in the phonetic realization of the vowels between the languages. In Czech, both long /uː/'s and short /u/'s are realized as fully back although there is an indication in the literature that short /u/ is somewhat lower and more front than its long counterpart (Skarnitzl & Volín 2012). In Southern British English (SBE) the GOOSE and FOOT vowels have in the last 4 or 5 decades undergone fronting, as has been documented both in production and in perception studies (e.g. Bauer 1985; Chládková & Hamann 2011; De Jong, McDougall, Hudson & Nolan 2007; Hawkins & Midgley 2005; Harrington, Kleber & Reubold 2008, 2011). Fronting of tense /u/ is reportedly affecting nearly all varieties of North American English (NAE; Labov, Ash & Boberg 2006; Labov 2008), with the front (and monophthongal) pronunciation being traditional in the US south (e.g. Koops 2010). Newer formant measurements reported for NAE (Clopper, Pisoni & De Jong 2005; Jacewicz, Fox & Salmons 2011) compared to older acoustic data (Peterson & Barney 1952; Hillenbrand, Getty, Clark & Wheeler 1995)[1] also seem to suggest fronting of the FOOT vowel. In addition, fronted high back vowels are described for English spoken natively in places other than the south of England or the US. Such fronting, characteristic for Scottish English (Macaulay 1977; Scobbie, Lawson & Stuart-Smith 2012), is further reported for dialects spoken in the north of England (Jansen 2010, Haddican, Foulkes, Hughes & Richards 2013), for Australian English (Cox 1999), English in New Zealand (Maclagan et al. 2009), or in South Africa (Mesthrie, 2010). Here we consider primarily SBE and NAE since these varieties are the main native pronunciation models for the majority of our learners.

Fronting of high back vowels in English affects both /u/ and /ʊ/ but the process is not completely aligned in time for the two vowels. Although in his newest revision of *Gimson's Pronunciation of English* Cruttenden presents fronting of both /u/ and /ʊ/ as well-established[2], i.e. pronunciation "which is now typical of the majority of GB[3]" (2014: 84), a closer look at the literature reporting on the topic suggests that, at least for the south of England, fronting of the FOOT vowel is a more recent development than fronting of the GOOSE vowel. Data from Hawkins and Midgley's acoustic study of Received Pronunciation (RP) vowels (2005) support this idea. Like many other studies, Hawkins and Midgley treat increased second formant frequency as the primary acoustic correlate of vocalic fronting. They show that only the oldest speakers, i.e. 65+ years, pronounce both GOOSE and FOOT as equally back, the other three groups always produce /u/ with a higher F2, i.e. as more front, compared to /ʊ/. The mean F2 of /u/ rises gradually across the four successive age groups, from older to younger, with the low-F2 fully back realization of /u/ evident only in the speakers over 65. On the other hand, the F2 frequency of /ʊ/ is low for three out of the four age groups, with only the youngest group of 20-25 year-olds showing raised mean F2. The over-65 speakers' values are in line with data in Deterding (1997). He reports similar F2 values for /u/ and /ʊ/ of males and somewhat higher F2 of /u/ than for /ʊ/ for the females in the 1980's BBC broadcasts corpus. Fabricius (2007) compared the position of the FOOT and LOT vowels in the vowel space across RP speakers of varying ages and identified those born in the 1970s as producing consistently fronted /ʊ/. By that time the fronting of GOOSE has already been under way and is commented on by Gimson in the first edition of his textbook (1966). In a cross-dialectal study of British English by Ferragne and Pellegrino

1 Peterson and Barney (1952) do not specify the origin of the speakers. Hillenbrand et al. (1995) report data for northern Midwest. Closest to that are the speakers from southeastern Wisconsin in Jacewicz et al. (2011).

2 Cruttenden includes also fronting of /ʊə /.

3 GB stands for General British, a term Cruttenden prefers to Received Pronunciation.

(2010), the 13 included accents patterned into three types: in some accents neither GOOSE nor FOOT vowels showed fronting, in other accents GOOSE but not FOOT was fronted, and in yet others both GOOSE and FOOT were rather front. No accents with fronted FOOT but not GOOSE were reported. Harrington and his colleagues (2011) analysed the tongue movements and positions of SBE speakers producing /u/, /ʊ/, /i/ and /ɔ/. They found articulation of /u/ to be as anterior as that of /i/, while the articulation of /ʊ/ was central between /i/ and /ɔ/. The authors conclude that "…the diachronic shift in /ʊ/ is likely to be a more recent innovation than that of its tense counterpart" (Harrington, Kleber & Reubold 2011:137).

With respect to the relative position of GOOSE and FOOT in the vowel space, American English differs from SBE. In American English the position of FOOT and GOOSE along the front-back dimension is reversed, with /ʊ/ being somewhat more front (Peterson & Barney 1952; Hillenbrand, Getty, Clark & Wheeler 1995). More recently, this pattern can be found in three out of six F1-F2 plots showing raw data from individual speakers from 6 regional dialect areas (Clopper, Pisoni & De Jong 2005). For the other areas, namely the South, the Midland and the West, /u/ is more advanced or it overlaps with /ʊ/ along the F2 dimension. This is due to the GOOSE vowel fronting, traditional in the South, an ongoing change in the other two regions (Labov 2008). The Atlas of North American English (ANAE; Labov et al. 2006) reports *u*-fronting being "general over almost all of North America, particularly after the coronal consonants" (2006: 154), with the extreme fronting found in the Midland and also in Toronto. The few geographical areas unaffected by *u*-fronting include the Minnesota-Wisconsin area and Eastern New England. The effect of the preceding coronal consonant is striking: in the ANAE survey, only a third of speakers with post-coronal *u*-fronting had a fronted /u/ after non-coronals. Importantly, the significant effect of age, i.e. younger speakers having higher F2 values compared to older speakers, signals a change over time. The data unfortunately do not show whether younger speakers show more coronal-context-free *u*-fronting. Neither Labov et al. (2006) nor other socio-phonetic sources reporting on American English explicitly mention diachronic shifting along the front-back dimension for the FOOT vowel.

What follows from this brief summary of English high back vowels for Czech EFL learners who do not live in an English-speaking community but encounter individual native speakers of diverse accents? It is clear that besides the relative scarcity of interactional native input, typical for foreign language learning, they face substantial inter-speaker variation – hearing native speakers produce both fronted pronunciations of the GOOSE (and possibly the FOOT) vowel as well as pronunciations without noticeable fronting. Together, these two factors, native input paucity and its inconsistency, may hinder the learners' noticing the phonetic detail in native L2 speech, and thus not allow for storing enough of the fronted exemplars and shifting their own pronunciation of English /u/ and /ʊ/ away from the fully back realization towards which they are biased by their L1.

2.1. Research questions

The present study examines production of English high back vowels in the speech of highly proficient Czech EFL learners. The aim of the study is twofold: (1) to establish whether Czech learners' production is constrained by the phonological mapping of the English tense-lax contrast on the Czech long-short contrast and (2) whether their production reflects any within-category phonetic shift towards the acquisition target driven by the dissimilarity of the L1 and L2 phones.

Bearing in mind the systemic differences between English and Czech vowels (namely the tense-lax distinction in English and the contrastive length in Czech), the phonetic differences between English and Czech high back vowels (fronted vs. fully back realizations), and the variation in the realization of the English /u/ and /ʊ/ between and within SBE and NAE, we formulated the following research questions:

(1) Do Czech EFL learners produce English /u/ - /ʊ/ as different in quality as well as quantity?
(2) Do Czech EFL learners produce English /u/ with any degree of fronting? If they do, the F2 values in their English productions will be higher compared to the reference value of Czech long /uː/.
(3) Do Czech EFL learners produce English /ʊ/ with any degree of fronting? If they do, F2 values in their English productions will be higher compared to the reference value for Czech short /u/.

Based on the literature reviewed above, we further hypothesize that the FOOT vowel will be fronted to a lesser degree in the learners' speech (FOOT-fronting being mostly less advanced in native speech) compared to the GOOSE vowel (which is relatively widespread in native speech).

3. Methodology

3.1. Participants

The participants were 20 learners of English as a Foreign Language. They were Czech female adults, students of the 'English for Interpreters and Translators' programme at Palacký University Olomouc. Their ages ranged from 19 to 27 years (M = 22). According to a language experience questionnaire administered after the data collection, our participants formed a fairly homogeneous group. Before reaching high school age, they all learned English as a foreign language in the Czech Republic via formal instruction with no systematic exposure to authentic English input. After the age of 15, their language experience became more diversified. Some learners encountered individual English native teachers at high school and some spent a limited amount of time in a native English environment.

At the time of data collection they continued to learn English in the Czech Republic, with the same exposure to native English at the university where they also attended a semester-long course in Engish phonetics with a focus on listening and phonetic transcription. The participants' use of English in their private life was more diverse. Table 1 in the Appendix summarizes the participants' responses to a short language experience and use questionnaire. All were L1-dominant but had become highly proficient in their L2 English, having achieved the proficiency level C1 or C2 in CEFR (Verhelst, Van Avermaet, Takala, Figueras & North 2009).

In addition to the learners' data, we also collected comparable baseline data from 5 native speakers available at the time of the recording, two male speakers of SBE (aged 40 and 52) and three speakers, one male and two females, of NAE. The female speakers were from Massachusetts (aged 24 and 54), the male speaker was from Oregon (age 41); all three spoke without a clear regional accent. With the exception of the older American female, who worked as a secretary in a small company, all the native speakers were teachers.

3.2. Reference values, procedure, stimuli

The study compared mean F2 values of English /u/ and /ʊ/ produced by the participants to the published reference F2 values for Czech long /uː/ and short /u/ (Skarnitzl & Volín 2012). Since all our participants were women, only the female values reported in the study were relevant.[4] The speakers in Skarnitzl and Volín's study, university students of linguistics aged between 20 and 30 years, are comparable to our participants in both educational background and in age. The method of data elicitation differs between the two studies. While the Czech participants in Skarnitzl and Volín read a continuous text, our EFL learners produced short sentences in a delayed repetition task. The procedure involved a participant hearing an English sentence (e.g. *Shoot in the air.*) followed by the English prompt *What should you say?* which was said by a different person. The participant responded using the quote frame *I should say, _* and said "I should say, Shoot in the air." The five native speakers who provided the baseline data did not complete the delayed repetition task but read the sentences off a computer screen and produced them in the frame *I should say, _*. A subset of each native speaker's sentences was included in the elicitation instrument used with the learners.

The elicitation material included 24 stimulus sentences, which either started or ended with a target word. The targets were 6 monosyllabic GOOSE words (*choose*, *goose*, *lose*, *move*, *shoot*, *soup*) and 6 monosyllabic FOOT words (*bush*, *book*, *good*, *hood*, *look*, *should*) occurring once in each sentence position (12 targets x 2 positions). Two methodological limitations were introduced into the study because this corpus of learner speech was collected as part of another project

4 In the paper, the female values are represented only in a figure; the exact numerical values were kindly provided by the authors.

(Šimáčková & Podlipský 2015). First, the project required the words to be unambiguously translatable from Czech into English. Because of prioritizing the translatability criterion, we did not control for the consonantal context of /u/ and /ʊ/ in the target words. It is known that preceding coronals favour higher F2 values and therefore, if the FOOT vowel was found to be less fronted then the GOOSE vowel, the difference could be attributed to the imbalance between the GOOSE and the FOOT stimulus sets with respect to the coronal context. Second, the design of the stimuli, with the placement of each target word once in the sentence-initial and once in the sentence-final position, was motivated by concerns of the original project and has less bearing on the current research questions. However, since speech tempo can vary sentence initially vs finally and we measure vowel durations, we monitor the factor of the target word placement in the current statistical analyses.

In addition to the 24 target stimulus sentences, 64 non-target sentences were also included. The non-target items, which served as data in another study, naturally did not contain initial and final GOOSE or FOOT words. The sentences were presented in random order using a Demo window script in Praat (Boersma & Weenink 2014) over Sennheiser HD 280 pro headphones and the production was recorded in a sound-treated booth using the built-in microphone of the Zoom Hn4 digital audio recorder at 44.1 kHz sampling, 16-bit quantization, without compression.

3.3. Analysis

In each elicited token of the GOOSE and FOOT words, vowel duration and frequencies of F1, F2, and F3 were measured. The onset and offset of the vowels was determined manually from the waveform with reference to the vocalic formant structure in the spectrogram. Formants were tracked using the Burg method in Praat, with the maximum formant value set to 3500 Hz and the number of formants to 3. Subsequently, the mean F1, F2, and F3 in the medial 50% of each vowel were computed in hertz. These acoustic measurements were then used to calculate the mean duration and the mean formant frequencies in hertz for each speaker's sentence-initial and sentence-final /u/ and /ʊ/. Tables 2 and 3 in the Appendix summarize these measurements separately for the learners and the native speakers. Subsequently, each speaker's raw frequency data were normalized using the Bark Difference Metric in NORM (Thomas & Kendall 2007). This normalization method expresses the degree of vowel frontness as the difference between Bark-converted F3 and Bark-converted F2 (Z3-Z2), as proposed by Syrdal and Gopal (1986): the smaller the difference, the more fronted the vowel. Vowel height is expressed as the difference between Bark-converted F3 and Bark-converted F1 (Z3-Z1): the smaller the difference, the lower the vowel. Mean values of the Z3-Z2 difference and the Z3-Z1 difference were calculated for each speaker's sentence-initial and sentence-final /u/ and /ʊ/.

4. Results

As expected, the Czech EFL learners differentiated the GOOSE and FOOT vowels in terms of duration, /u/ being 1.5 and 1.4 times longer than /ʊ/ sentence initially and finally, respectively (see Table 1). A 2-by-2 repeated-measures analysis of variance (ANOVA) with Vowel (/u/, /ʊ/) and Position (initial, final) as the within-participant factors confirmed a significant main effect of Vowel on duration ($F[1, 19] = 197.98$, $p < .001$). The effect of Position was also significant ($F[1, 19] = 130.31$, $p < .001$), reflecting final lengthening. Despite the difference in the GOOSE-to-FOOT durational ratio sentence initially and finally, no interaction between Vowel and Position was found. Table 1 compares the group mean durations of /u/ and /ʊ/ produced by the learners in sentence-initial and sentence-final words to the baseline native English data. The learners' GOOSE-to-FOOT durational ratio initially and finally is somewhat lower than that of the native speakers (1.6 in both positions).

Table 1. Mean durations (and standard deviations) of /u/ and /ʊ/ in the sentence-initial and sentence-final GOOSE and FOOT produced by the EFL learners and English native speakers.

	/u/ duration (ms)				**/ʊ/ duration (ms)**				**/u/ to /ʊ/ ratio**			
	initial		final		initial		final		initial		final	
	mean	*SD*	mean	*SD*	mean	*SD*	mean	*SD*	mean	*SD*	mean	*SD*
EFL Learners	104	*15.6*	154	*26.4*	69	*9.2*	113	*16.7*	1.5	*.22*	1.4	*.19*
Native speakers	106	*2.1*	183	*40.1*	67	*9.2*	118	*2.1*	1.6	*.15*	1.6	*.23*

In terms of spectral quality, the two high back vowels also differed from each other in the learners' productions. For the sake of comparison with the baseline English native data, collected both from women and men, normalized formant values were used in the following analyses. Individual participants' mean Z3-Z2 and Z3-Z1 differences were submitted to two repeated-measures ANOVAs with the within-participant factors Vowel and Position. With respect to the Z3-Z1 difference reflecting vowel height, the analysis revealed a significant main effect of Vowel ($F[1, 19] = 81.244$, $p < .001$). No significant effect of Position alone was found but there was a significant interaction of Vowel and Position ($F[1, 19] = 5.7137$, $p < .05$). A post-hoc Tukey test showed that learners' GOOSE and FOOT vowels differed in vowel height only in the focal sentence-final position (F3-F1 was significantly smaller for the lax vowel, i.e. the vowel was lower, $p < .01$).

The repeated measures ANOVA with mean Z3-Z2 values as the dependent variable also found a significant main effect of Vowel ($F[1, 19] = 36.764$, $p < .001$). The group mean Z3-Z2 difference of GOOSE was smaller, i.e. the vowel was more front, compared to that of FOOT. Position was not found to have a significant effect and neither was there a significant interaction between Position and Vowel: /u/ was more fronted compared to /ʊ/ in both positions. Caution, though, is required when interpreting this result since, as mentioned earlier, the coronal context, somewhat more frequent in our GOOSE target words, favours fronting.

Tables 2 and 3 also compare the learners' group mean values of Z3-Z1 and Z3-Z2 to the baseline native English data. It is clear from this comparison that native speakers produced a greater difference between the GOOSE and FOOT vowels both in Z3-Z1, a correlate of vowel height, and in Z3-Z2, i.e. in the degree of frontness. For both dimensions, the /u/ – /ʊ/ difference is about three times greater in the native English speech and therefore the spectral differentiation of the vowels is greater.

Table 2. Group mean difference between Bark-converted F3 and Bark-converted F1 (Z3-Z1) of /u/ and /ʊ/ (with standard deviations) averaged across sentence positions.

Z3-Z1	**/u/**		**/ʊ/**		**/u/ - /ʊ/ diff**	
(vowel height)	mean	*SD*	mean	*SD*	mean	*SD*
EFL Learners	10.999	*.475*	10.629	*.518*	.370	*.185*
Native speakers	11.171	*.172*	10.004	*.419*	1.167	*.252*

Table 3. Group mean difference between Bark-converted F3 and Bark-converted F2 (Z3-Z2) of /u/ and /ʊ/ (with standard deviations) averaged across sentence positions.

Z3-Z2	**/u/**		**/ʊ/**		**/u/ - /ʊ/ diff**	
(vowel frontness)	mean	*SD*	mean	*SD*	mean	*SD*
EFL Learners	3.849	*.894*	*4.250*	*.710*	− .401	*.297*
Native speakers	3.013	*.793*	*4.289*	*.326*	−1.276	*.893*

Dispersion of the individual spectral values measured for learners and native speakers can be assessed in Figure 1. It shows Z3-Z1 by Z2-Z1 scatter plots of the two groups' tokens of each of the GOOSE vowels (left) and the FOOT vowels (right) measured. Although not all learners display the same degree of fronting of /u/ as the five native English speakers, we can see that the native speaker data points completely overlap with the learner values. Likewise, the range of native values for /ʊ/ is contained within the learners' range for this vowel, which reaches to somewhat lower, i.e. less fronted, values. In Figure 2, the scatter plot of individual speakers' mean Z3-Z2 differences of /ʊ/ against mean Z3-Z2 differences of /u/ shows that for most participants in the study the fronting of the FOOT vowel and of the GOOSE vowel go together. A Pearson's correlation confirmed a fairly strong positive relationship between the two variables ($r = .79$, $p < .001$). When the native speakers are excluded from the analysis, the strength of the correlation increases ($r = .96$, $p < .001$). Therefore, for the Czech EFL learners the fronting of the GOOSE and FOOT vowels was linked very closely.

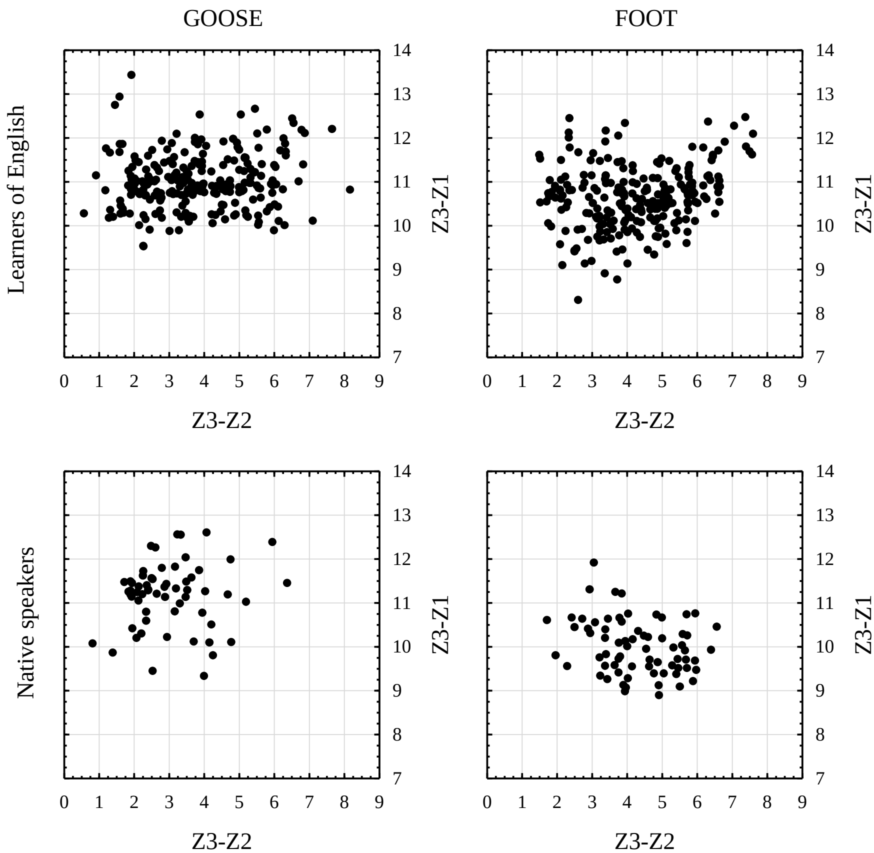

Figure 1. Scatterplots of Czech learners' and native speakers' GOOSE and FOOT vowels. Z1, Z2, and Z3, respectively, correspond to F1, F2, and F3 in Bark.

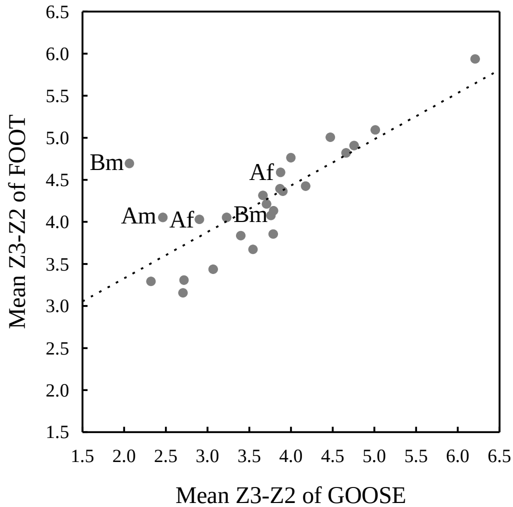

Figure 2. Scatterplot of individual speakers' mean Z3-Z2 differences of /ʊ/ against mean Z3-Z2 differences of /u/. Z1, Z2, and Z3, respectively, correspond to F1, F2, and F3 in Bark. The smaller the Z3-Z2 difference, the fronter the vowel. Letters indicate female and male NAE speakers (Af, Am) and male SBE speakers (Bm).

The GOOSE and FOOT fronting realized by the Czech EFL learners was further assessed vis-à-vis the published female reference values of Czech long /uː/ and short /u/ (Skarnitzl & Volín 2012). For this purpose, the learners' mean F2 values in hertz were averaged across sentence positions. A *t*-test for single means, testing the averaged F2 values of the learners' GOOSE vowel against the reference value of 757 Hz (long Czech /uː/) found that they were significantly higher ($t[19] = 17.27$, $p < .001$). Likewise, a *t*-test for single means testing averaged F2 values of learners' FOOT vowel against the reference value of 1135 Hz (short Czech /u/) showed that they were significantly higher ($t[19] = 8.93$, $p < .001$). In other words, the Czech EFL learners' English /u/ and /ʊ/ were more front (had higher F2) than the Czech native speakers' mean long /uː/ and short /u/ reported in Skarnitzl and Volín (2012).

5. Discussion

To recapitulate, the goal of this study was to examine whether limitations on the quantity and consistency of interactional native speaker input, that characterize foreign language learning, prevent L2 learners from fine-tuning their phonological representations of L2 vowels and consequently their phonetic realizations. The selected test case was the production of the English high back vowels /u/ and /ʊ/ by Czech EFL learners whose L1 contrasts long and short /uː/–/u/. We considered the relative role of duration and spectral quality in the learners' productions and, importantly, the degree of vocalic fronting, as indexed by differences between Bark-converted values of F3 and F2 formants.

The duration data are consistent with the prediction that the Czech EFL learners interpret the English GOOSE – FOOT contrast in terms vocalic length and categorize English /u/–/ʊ/ as a long vs. short vowel, vowel length being contrastive in their L1.The learners clearly differentiated between the GOOSE and FOOT vowels in duration, producing shorter /ʊ/ in FOOT as compared to /u/ in GOOSE. However, despite coming from a length-contrasting L1, they did not exaggerate the duration difference. Their /u/-to-/ʊ/ duration ratio was even slightly lower than the native speakers' baseline. Based on recent reports on vowel durations in Czech, we suggest that the learners are not only reusing the L1 phonological length feature but also the specific L1 high-back vowel durational settings. In Czech, the durational difference between /uː/–/u/ seems to have decreased as a result of the two vowels separating somewhat in their spectral quality, following the already qualitatively differentiated and durationally converging high front vowels. Recently, the long-to-short ratio of non-final vowels was reported to be 1.83 for /aː/–/a/, 1.23 for /iː/–/ɪ/ and 1.42 for /uː/–/u/ (Podlipský, Skarnitzl & Volín 2009; Skarnitzl 2012). The last duration ratio corresponds closely to our EFL learners' /u/-to-/ʊ/ ratio for the sentence-final position of the target words.

The learners also produced statistically significant spectral differences between the FOOT and GOOSE vowels. Thus we can answer our first research question in the affirmative: Czech EFL learners can produce the English high back vowels as different in quality. However, we should also note that the magnitude of their formant /u/ – /ʊ/ differences was relatively small compared to the English native speaker baseline. In fact, the learners' English tense and lax /u/ – /ʊ/ were spectrally closer than the equivalent Czech long /uː/ and short /u/ of the young Czech female speakers in Skarnitzl and Volín (2012). In addition, the prevalence of the coronal context among the GOOSE target words is likely is likely to have augmented the difference between /u/ and /ʊ/ on the front/back dimension. A further indication that for the learners, unlike for the native speakers, /u/ – /ʊ/ are connected in quality, is the strong correlation between the fronting of /ʊ/ by a particular learner and her fronting of /u/. In other words, our learners seem to treat the L2 vowels as a pair, distinguished in quantity and slightly also in quality (in parallel to their treatment of Czech /uː/–/u/).

Fronting in the Czech EFL learners' pronunciation of both English /u/ and /ʊ/ was evident when their F2 values were matched with those produced in Czech /uː/ and /u/ by a comparable group of Czech speakers. The group mean F2 value of the learners' English GOOSE (1562 Hz) differs clearly from the Czech reference /uː/ (757 Hz), even when the coronal bias in our GOOSE target words is taken into consideration. The difference between the learners' English FOOT and the Czech reference /u/ is smaller but still substantial (group means of 1459 Hz vs. 1136 Hz respectively). Thus, it is clear that the phonetic quality of the L2 high back vowels was not constrained by equivalence mapping of the English /u/–/ʊ/

contrast onto the /uː/–/u/ distinction in Czech. With respect to our second and third research questions we can conclude that Czech EFL learners can learn to produce English high back vowels with a degree of fronting. Apparently, the L1-Czech and L2-English vowels are sufficiently dissimilar along the front-back dimension for the learners to detect the difference. Based on the perception-first assumption, we conclude that in the course of L2 learning these EFL learners had been able to exploit the acoustic properties of the native speakers' realizations of /u/ and /ʊ/ they had encountered and created new L2 phonetic targets. This phonetic refinement took place despite the fact that the amount of phonetic manifestations of native /u/ and /ʊ/ in the interactional input was severely constrained compared to the rich exposure when L2 is the ambient language. We can speculate that learning of phonetic detail was boosted by the intensive exposure of these learners to non-interactional audio input during their training as interpreters.

As already pointed out, the fronting of the GOOSE and FOOT vowels correlated closely across the learners in the sample. Such result is interesting since the fronted realizations of FOOT are much less consistently present across SBE and NAE varieties of English and consequently they were less likely to be present in our leaners' input. Neither is FOOT fronting consistently present in the model target words used in the delayed repetition task (two out of our five native speakers did not have fronted FOOT at all and one produced only modest FOOT-fronting). This suggests that back-vowel fronting in learners' speech is not simply a result of imitation. Instead, we interpret the parallel fronting of GOOSE and FOOT vowels as a manifestation of parsimony that constrains phonological and phonetic representations in multilinguals. The Czech learners of English achieve the FOOT–GOOSE contrast by efficiently reusing a feature which has a distinctive function in their L1, namely length, and rely less on new height and/or front-back distinctions. Also quite efficiently, they approximate phonetic accuracy of FOOT and GOOSE by fronting both vowels.

6. Conclusion

Three converging findings lead us to the conclusion that our learners reuse their L1 high-back vowel categories while at the same time updating these categories to reflect new L2 phonetic detail. First, it is the durational, and second, the spectral differentiation of the GOOSE and FOOT vowels. Both are similar to L1 differentiation between /uː/–/u/. Third, the degree of fronting of one of these L2 vowels closely parallels the fronting of the other vowel, indicating a qualitative link between them. This seems to be an optimal parsimonious solution for a Czech learner of English, resulting in relatively native-like production (and indeed perhaps perception) while maintaining a common length feature for the L1 and L2.

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Appendix

Table 1. Language experience questionnaire: Learner number, chronological age; age at the onset of learning; learning experience at elementary school age and high school age (extended English language instruction, contact with a native English teacher, time spent in an English-speaking country); current use of English outside university (minimum estimated contact with native speakers, minimum estimated exposure to English in media)

			Elementary school age			High school age			Current lang. use	
No.	Age	AOL	Ext. Eng. instr.	Native English teacher	Time abroad	Ext. Eng. instr.	Native English teacher	Time abroad	Min. interact. with NS	Min. media exp.
1	25	9	No	No	No	No	Yes	5 moss	1x/ mo	1 h/d
2	19	8	Yes	No	No	Yes	No	No	1x/ mo	3 h/d
3	24	10	No	No	No	No	No	6 mos	2x/ y	2 h/wk
4	19	7	Yes	No	No	No	Yes	No	2x/ y	1 h/d
5	21	9	No	No	No	No	No	4 mos	1x/ mo	3 h/d
6	21	9	Yes	No	No	No	Yes	7 mos	2x/ y	10h/mo
7	21	11	No	No	No	No	Yes	3 mos	1x/ y	3 h/d
8	23	11	No	No	No	No	No	4 mos	daily	2 h/d
9	27	10	No	No	No	Yes	No	No	none	1 h/d
10	27	5	No	No	6 mos	Yes	No	12 mos	2x/ wk	1 h/d
11	25	6	Yes	No	No	Yes	No	10 mos	none	2 h/d
12	19	8	No	No	No	No	Yes	No	1x/ y	1 h/d
13	19	8	No	No	No	Yes	No	No	1x/ y	2 h/d
14	20	9	No	No	No	No	Yes	No	1x/ mo	2 h/d
15	20	11	No	No	No	No	Yes	No	2x/ y	2 h/d
16	21	11	Yes	No	1 mo	No	No	No	1x/ y	1 h/d
17	22	10	No	No	No	No	No	1 mo	daily	5 h/d
18	19	9	No	No	No	No	No	No	1x/ wk	2 h/d
19	22	9	No	No	No	Yes	No	No	2x/ wk	1 h/d
20	21	6	No	No	No	No	No	No	none	1 h/d

Table 2. Mean formant frequencies of the GOOSE and FOOT vowels per learner (Hz)

learner noumber	GOOSE			FOOT		
	F1	F2	F3	F1	F2	F3
1	450	1714	2539	530	1590	2604
2	374	1900	2689	438	1655	2684
3	406	1381	2786	430	1260	2614
4	379	1539	2515	426	1476	2597
5	383	1565	2678	414	1446	2739
6	395	1354	2733	419	1318	2729
7	438	1558	2609	530	1556	2683
8	398	2073	3063	417	1809	2867
9	409	1452	2592	463	1294	2623
10	396	1766	3105	418	1752	3095
11	375	1549	2702	420	1450	2759
12	396	1630	2585	405	1441	2590
13	418	1392	2697	452	1295	2722
14	431	1310	2759	440	1265	2697
15	428	1605	2794	472	1510	2781
16	404	1629	2551	444	1509	2499
17	470	1602	2774	478	1465	2723
18	380	1614	2861	437	1493	2846
19	375	1143	2918	395	1207	2911
20	408	1456	2683	446	1393	2687
Mean	406	1562	2732	444	1459	2723

Table 3. Mean formant frequencies of the GOOSE and FOOT vowels per native speaker (Hz). Letters identify female and male NAE speakers (Af, Am) and male SBE speakers (Bm); numbers after the comma represent speakers' ages

Native speakers	FOOT			GOOSE		
	F1	F2	F3	F1	F2	F3
Af, 24	492	1495	2709	380	1776	2712
Af, 54	557	1387	2736	406	1557	2765
Am, 41	411	1430	2614	299	1726	2493
Bm1, 40	458	1194	2423	326	1791	2449
Bm2, 52	387	1199	2203	331	1426	2504
Mean	461	1341	2537	348	1655	2584