Phonological Length of L2 Czech Speakers' Vowels in Ambiguous Contexts as Perceived by L1 Listeners

Jitka Veroňková(✉) and Tomáš Bořil

Institute of Phonetics, Charles University, Prague, Czech Republic
{jitka.veronkova, tomas.boril}@ff.cuni.cz

Abstract. The paper focuses on the vowel length of non-native speakers' Czech and their perception by native speakers. Due to its phonological status, the length of vowels in Czech is an important sound feature. Its improper realization can result in communication breakdown. From the Czech read speech of 8 Russian and Ukrainian female speakers, a perception test was created: 78 items consisting of 5 pairs and 1 triad of the same sentences that differed only in the target word. These two-syllable words were distinguished by a combination of short/long vowels, e.g., /lanu/ – /la:nu/, /la:nu/ – /la:nu:/. The L1 Czech listeners rated the degree of the foreign accent of the items and intelligibility of the target words. The agreement of listeners with the speakers' intent is evaluated, and the types of substitutions are analyzed in particular with respect to the combination of short/long vowel and the position of a stressed/unstressed syllable. The vowel duration and the formants of i-vowels were measured. In the second perception experiment, durations of both vowels in /lanu/ were manipulated in the range from 60 ms to 240 ms and native Czech speakers rated their perceived length.

Keywords: Czech as L2 · Vowel length · Duration · Formants · Intelligibility · Foreign accent · Perception

1 Introduction

One of the foundations for successful communication in a foreign language is an appropriate acquisition of target language sound features. Vowel length belongs among the segmental phenomena that cause difficulty in production and perception for speakers of Czech as L2 [1, 2].

Even languages from one language group may differ in the treatment of vowel length. Slavic languages, including Czech, may serve as an example. For instance, Croatian uses length as one of its distinctive features, while Polish vowel system contains just short vowels, unlike, e.g., Russian and Ukrainian, where variability in vowel quantity is present; however, it does not have phonological status; it is a feature governed by the word stress (similarly to, e.g., English or German) [3].

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1.1 Vowel Length in Czech

In Czech, the vowel length is phonological. Two grades – short and long – are discriminated, and in the original vocabulary or grammatical endings, the long vowel is consistently marked in orthography. Vowel length distinguishes either lexemes, e.g., *dráha* (track; lane) – *drahá* (expensive; dear), or grammatical forms, e.g., *pracovat* (to work): *pracuji* ([I] work) – *pracují* ([they] work). Its incorrect pronunciation may result in difficulties understanding the speech or even change the meaning completely. Vowel length is fully independent of word stress in Czech, which is fixed on the first syllable of a word. The stressed syllable can be long or short with long syllables being not limited to a specific position within a word. Individual words may contain more long vowels or no long vowels at all.

In Czech, phonological length is acoustically manifested mainly in vowel duration; the latest data shows long/short duration ratio of 1.6 to 1.8 [4]. I-vowels are an exception with their vowel quality also contributing to the differentiation between short and long variants (short [ɪ] is more open than long [i:]), especially in the Bohemian part of the Czech Republic [5–7] and the ratio is lower (around 1.3) [4]. According to recent studies, spectral cue can contribute to the distinction between short and long variants in case of high back vowels as well [7].

Vowel duration is influenced by a variety of factors, such as the vocal quality itself (high vowels tend to be shorter than low ones), word stress (this factor is not applicable to Czech in such an extent), the phonetic neighborhood, position in the sentence, speech rate, etc., cf. [8–10]. Openness/closeness of syllable was recognized as an important factor for Czech [11].

1.2 Vowel Length for L2 Czech Speakers

L2 speakers can use different vowel length patterns because of negative transfer from their mother tongue or other foreign languages to Czech as the target language [12]. L1 listeners repeatedly report errors in vowel length in the speech of Czech L2 speakers as disturbing and contributing to foreign accent. In [13], the native Czech listeners evaluated the acceptability of L2 Czech speakers' speech (L1 Russian) and then specified the phonetic features that had influenced their evaluation. Approximately two-thirds of the comments referred to the segmental level, with one-third of that number to vowels. As for vowels, twice as many comments were about their length.

As follows from perception analyses, a widespread error of L2 Czech speakers is mixing of length and word stress, especially improper lengthening of the canonically short stressed syllable [2, 14] (L1 Russian); the difficulty for L2 Czech speakers lies in estimating adequate vowel duration – the canonically long vowels are often realized as half-long [2] (L1 Russian); the pronunciation of two adjacent long vowels is difficult [15] (L1 Polish). Errors in the production of vowel length are attested for advanced speakers as well [2, 13, 15].

The focus of this paper is the vowel length of L2 Czech speakers with Russian and Ukrainian mother tongues as perceived by L1 Czech listeners. Four novel aspects compared to the previous studies are presented. Unlike previous studies, this paper seeks to limit the role of content when perceiving the length, therefore an ambiguous

context was chosen (experiment 1) or the stimuli were tested without context (experiment 2); measurement of vowel duration and partially spectral analysis was performed; vowel duration in the stimuli was manipulated (experiment 2); in both experiments, perception tests were administered.

Four main dimensions according to which L2 speech may be characterized are attested: foreign accent, comprehensibility, intelligibility and fluency [16]. The perceptual task in our experiments corresponds to intelligibility, defined here as "the extent to which a speaker's message is actually understood by a listener" [17]. This concept is not identical with the overall understanding of the content [18]. Apart from intelligibility, the degree of foreign accent was also examined. Testing both of these dimensions is another contribution of this paper.

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2 Method

2.1 Experiment 1

Material. For the purpose of broader research concerning Czech as L2, a database of L2 Czech speakers' recordings was acquired. Recordings were taken in a sound-treated and sound-proofed room (AKG C 4500 B-BC microphone, sample rate 48 kHz, 16-bit depth). From the collection of database texts, 13 sentences focusing on vowel duration in ambiguous context were selected (see Table 1): 5 pairs and 1 triad of the same sentences differed only in the target word. These target words were distinguished by a combination of short (S)/long (L) vowels. The target words were disyllabic, and their structure was CVCV, so all the vowels occurred in open syllables to eliminate the factor of syllable openness/closeness. No ambiguity in their correct pronunciation in standard Czech has been attested. All the remaining words in the sentence (and even the preceding sentence) contained only short vowels so that the linguistic surrounding does not affect the S/L pattern of the target word pronunciation. The target word was placed in the middle of the sentence in order to reduce the potential influence of the phrase juncture. In the text for recording, the sentences were mixed among others to mask the target sound phenomena.

Speakers. A group of speakers consisted of 8 female speakers; L1: 4 Russians, 3 Ukrainians, 1 Ukrainian/Russian. Age: 18–37; Czech proficiency: level B1–C1 according to CEFR [19] (students of Czech study programme, of a non-linguistic programme and of Czech language courses at Charles University, Prague).

Perceptual Test. The 13 sentences (see Table 1) formed the basis of the perception experiment. Some of their realizations were excluded because of slips of tongue. Finally, six realizations of each sentence were used in the experiment, i.e., 78 items in total (13 sentences, 6 realizations each; 9–10 items of each speaker), as a compromise between a sufficient number of items and a reasonable length for listeners.

Two sections of the experiment were created and, in each section, the same set of the 78 items was tested. In the first section, the listeners determined the degree of foreign accent on a 7-point symmetrical scale for each item (1 – no foreign accent, 4 – middle foreign accent, 7 – completely foreign). In the second section, they determined on the same set of 78 items, which version they heard: On the screen, they saw four variants, i.e., S/L combinations of a target word written in a phonological transcription, e.g., /viru/, /viru:/, /vi:ru/, /vi:ru:/. Phonological transcription was used intentionally instead of orthography to support the focus of listeners on the segmental intelligibility task, not on the content of the sentence. [18] For the same reason, all four versions of S/L combinations were used even if they do not appear in Czech (e.g., /lanu:/) or if the form does not fit lexically or grammatically in the carrier sentence.

Table 1. List of sentences in perception experiment.

(1) *Tyhle* ***valy / vály*** *ze dřeva budily pozornost.* (SS–LS)
These wooden *pastry boards* / *mounds* attracted attention.
(2) *Podle něj se chlapci* ***myli / mýlí*** *poměrně často.* (SS–LL)
In his view, boys *washed themselves* / *are wrong* quite often.
(3) *K jednomu* ***lanu / lánu*** *poslali dobropis.* (SS–LS)
To one *rope* / *large field*, they sent a credit note.
(4) *Sklizeň* ***lánu / lánů*** *trvala až do večera.* (LS–LL)
Harvesting *the large field* / *fields* lasted until the evening.
(5) *Text o vlastnostech* ***viru / virů / výrů*** *publikovala v časopise.* (SS–SL–LL)
In a journal, she published a text about attributes of *a virus* / *viruses* / *eagle owls*
(6) *Uprostřed* ***víru / vírů*** *plavaly rybky.* (LS–LL)
Fish swam in the middle of *a swirl* / *swirls*.
Note: 1) *ů* is just a graphic symbol, the sound is the same as with *ú* /u:/. 2) In Czech, there is no difference between *i/y*, *í/ý* pronunciation (unlike [i]/[ɨ] in Polish, Russian and Ukrainian).

The experiment was designed using Praat MFC (multiple forced-choice) environment [21]. Each section was preceded by a training part containing 5 items. Within each section, items were played in a random order, divided by a short break with a piece of music after every 20 items. In the first step, the accent section was conducted, and after a break, the intelligibility section followed. It was possible to replay each item up to three times.

Listeners. A group of listeners comprised 13 native listeners, students of the Phonetic programme (Faculty of Arts, Charles University, Prague). The experiment was conducted individually or in a small group; the listeners used headphones.

Acoustic Analysis. Perception analysis was supplemented by acoustic measurement of vowel duration. The items were manually labelled according to the rules set out in [20] using Praat software [21]. Normalized vowel durations were obtained as follows: For each target word, articulation rate was measured in syll/s. A mean articulation rate of each speaker was calculated from these values. Normalized vowel duration was computed by multiplication of the real duration by the mean articulation rate of the

speaker and divided by total mean articulation rate of all speakers together. This procedure makes it possible to compare vowel duration among speakers.

As stated in 1.1, the real duration of i-vowels may not be the only or the main cue of perceived vowel length for native Czech. For these vowels, mean F1 and F2 formant frequencies in the middle third of their duration were analyzed using Burg method, looking for five formants in the range of maximum frequency of 5500 Hz in Praat [21]. These values were manually corrected according to visual inspection of spectrogram and audio listening to avoid nasal formants mismatch and other possible errors of the automatic algorithm.

2.2 Experiment 2

To evaluate the effect of vowel duration on perceived length, a perception experiment consisting of words /lanu/ with manipulated vowel durations was created. Both vowels were manipulated to five durations (60, 85, 120, 170, and 240 ms) yielding 25 combinations (five /a/-durations x five /u/-durations). The manipulations were performed in Praat [21] using the pitch-synchronized overlap-and-add method. Words by two speakers from the material of experiment 1 were used, thus the total number of items-of-interest was 50. Additional 18 non-manipulated two-syllable words with mixed short and long vowels were included into the set as distractors. The perception experiment was evaluated by 17 native Czech listeners; items introduced by a short desensitization beep sound were played in random order for each subject in Praat MFC environment [21] with 4 possible answers combining short/long choice for both vowels.

3 Results

3.1 Assessment of Foreign Accent and Intelligibility

Concerning the question of accent, listeners used all the points from the scale including the extreme points in certain utterances. From all the single judgements, a mean value of individual speaker's accent was calculated. This mean accentedness ranged from 2 (very weak accent, 2 speakers) to 5 (strong accent, 4 speakers), i.e., nobody sounded accentless or with a very strong accent or even completely foreign.

Speakers also differed in terms of intelligibility of target words. The frequency of the listener marking the target word in accordance with the speaker's intent was counted, and, in case of disagreement, the types of patterns involved were analyzed (for the relation between accent and intelligibility see Fig. 1). All the listeners' judgments are grouped by the accent mark, and for each group, a mean value of intelligibility is evaluated. With a higher degree of accent, the level of intelligibility decreases.

However, the relationship is not straightforward, as the assessment concerning single speakers shows. There was one speaker with a very high intelligibility (91%) and a very weak accent; the assessment of the two parameters is thus in accordance. On the contrary, another speaker with a very weak accent showed a discrepancy. Intelligibility of this speaker was much lower, around 50%. Three more speakers achieved similar

intelligibility, but their accent was more perceptible, ranging from weak to strong. Concerning three speakers (all with a strong accent), the listeners identified around a third of target words correctly. This finding is in accordance with [16:1–6] that intelligibility and accentedness are partially independent.

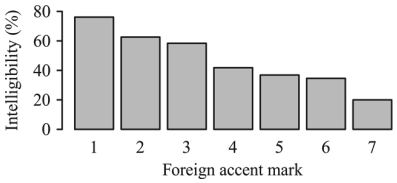

Fig. 1. The relation between foreign accent and intelligibility on the base of all the judgements.

3.2 Assessment of Individual Target Words

Regarding the segments, 49.2% of vowels were perceived in accordance with the speakers' intent, and 50.8% incorrectly, of which 42.6% were originally short and 57.4% were originally long. Regarding the target words, 47.3% of perceived variants corresponded to the canonical form, while 52.7% differed. Tables 2a)–d) show the perception of target words ordered according to their original S/L pattern.

Table 2 Intelligibility of target words: (a) SS, (b) LS, (c) LL, (d) SL. Columns: perceived variants – number of assessments. Bold numbers with asterisk: correct match, bold without asterisk: mismatch that fits into the sentence, plain: mismatch that does not fit into the sentence (semantic or grammar problem or the word does not exist).

(a)	SS	SL	LS	LL
valy /vali/	**56***	1	**20**	1
myli /mili/	**45***	5	24	**4**
lanu /lanu/	**30***	3	**44**	1
viru /viru/	**11***	**12**	**48**	**7**
Sum	142	21	136	13
%	45.5	6.7	43.6	4.2

(b)	SS	SL	LS	LL
vály /va:li/	**29**	0	**48***	1
lánu /la:nu/	**15**	0	**63***	0
lánu /la:nu/	9	2	**61***	**6**
víru /vi:ru/	2	5	**54***	**17**
Sum	55	7	226	24
%	17.6	2.2	72.4	7.7

(c)	SS	SL	LS	LL
mýlí /mi:li:/	**30**	5	37	**6***
lánů /la:nu:/	8	2	**46**	**22***
výrů /vi:ru:/	**8**	**20**	**22**	**28***
vírů /vi:ru:/	0	6	**33**	**39***
Sum	46	33	138	95
%	14.7	10.6	44.2	30.4

(d)	SS	SL	LS	LL
virů /viru:/	**2**	**17***	**41**	**18**
%	2.6	21.8	52.6	23.1

Among the realizations of the original SS words (i.e., both short vowels), two patterns prevailed. The SS pattern (following the original form), and the LS pattern (the first, i.e., stressed, syllable long). In total, both variants are perceived equally (with 45.5% for the former and 43.6% for the latter). Concerning single items, two words – /vali/ and /mili/ – were identified with greater certainty, as opposed to /lanu/ and /viru/, in which the incorrect variant LS prevailed. In case of the word /mili/, the variant LS does not even fit into the sentence.

The original LS words (i.e., the first vowel long) were predominantly perceived following the canonical form (72.4%). Concerning the word /va:li/, the listeners evaluated the length of the first vowel in 25.6% as phonologically short (SS). The same SS pattern also occurred in the perception of the word /la:nu/ and the LL pattern in the word /vi:ru/. All the incorrect variants mentioned above fit into the sentence.

Comparing the original LL words (i.e., both vowels long) to the SS and LS words mentioned above, the layout of the perceived variants was somewhat more varied. In total, the highest score was achieved in the case of the LS pattern (i.e., with the second vowel short), although the predominance was not that apparent (44.2%). This LS pattern was also found in the word /mi:li:/, although it did not fit into the sentence. The second most frequently used pattern was the agreement with the speaker's intent (LL pattern), however, its value was not so considerable (30.4%). Additionally, in the perception of the word /mi:li:/, the LL pattern occurred in small numbers; apart from the LS pattern, this word was perceived as SS, i.e., with both vowels short. The short vowel in the first syllable also occurred in the word /vi:ru:/ with the orthographic form *výrů*.

The SL pattern was tested on just one target word. The dominant variant perceived is the LS pattern (52.6%). Compared to this one, the SL pattern, which follows the speaker's intent, did not reach even half the LS size of the agreement, similarly to the LL pattern.

The most frequent pattern among the variants perceived in the disagreement with the speaker's intent was the LS pattern (59.0%). The exchanges occurred even in the items assessed by some listeners as accentless: SS>LS (lengthening of the first stressed syllable): *lanu>lánu* (62%), *viru>víru* (56%) – 5 judgements indicating the item as accentless; LL>LS (shortening of the last syllable, difficulties pronouncing two adjacent long vowels): *lánů>lánu* (59%), *mýlí>míli* (47%), *vírů>víru* (42%) – 12 judgements indicating the item as accentless; SL>LS (shift of a long vowel to the first, stressed syllable): *virů>víru* (53%); 4 judgements.

These findings are consistent with Gersamia's data [14], who analyzed the realization of three-syllable words with different S/L patterns in Czech read texts of L1 Russian speakers. The most common patterns used by the speakers were LSS and SLS patterns, i.e. patterns with only one long vowel that was mostly associated with word stress (in the SLS pattern, speakers predominantly produced word stress on the second syllable). The patterns containing two adjacent syllables were produced by speakers very rarely.

A question may be asked whether the distribution of patterns (Table 2) is not affected by the frequency of single variants in the Czech corpus. In the spoken corpus [22], which is less extensive, the absolute frequency of the variants involved is very low, so we chose the written corpus [23]. Due to the extensive word homophony

and homonymy of endings within the lexeme, it is not easy to obtain comparable data. However, it is possible to make the following assertions:

Of the words /vali/ and /va:li/, which meet the grammatical and lexical requirements of the SS carrier sentence, the word /vali/ is significantly more frequent; here (Table 2a), therefore, the perception of the correct SS pattern could be supported by frequency. In case of the words /lanu/ and /la:nu/ (dative case that fits into the SS carrier sentence), the SS word /lanu/ is more frequent, but the LS pattern prevails in the perception of the SS word /lanu/ (Table 2a), unlike in the previous case.

The SS word /mili/ is also common (*myli* – instances per million (imp) 0.49), but the LL word /mi:li:/ (in written form *mýlí*) has the highest frequency of all words used in the experiment (*mýlí* – imp 3.29). [23] However, the perception of this LL word is very low (see Table 2a and 2c). We believe that the vowel quality plays a role especially in the first syllable (see Sect. 3.3). The LS pattern /mi:li/ was perceived in a significant volume instead of the SS pattern; this LS word exists in Czech, but does not fit into the SS carrier sentence. This observation is consistent with the assumption that L2 Czech speakers (L1 Russian and Ukrainian) tend to lengthen a short stressed syllable. (This assessment is also a proof that the listeners performed the task as expected, i.e., that they focused on the intelligibility of the target words, rather than on the content of the whole sentence).

In addition to the last word /viru/, all the other three words fit into the SS carrier sentence (see Table 2a). Regarding the frequency, apart from the LL word /vi:ru:/ with lower (*vírů*) and very low (*výrů*) frequency, the frequency of other words (SS, LS, SL) suitable for carrier sentences is higher and comparable (imp 2.01–2.53) [23]. However, in the perception of the SS carrier sentence, a clear preference for the LS pattern can be observed (see also Table 2b and 2d). The quality of i-vowels may influence perception here as well.

From the above observations, we believe that the frequency of variants in the corpus does not play a large role in our experiment.

3.3 Objective Measurements

Figures 2a and 2b depict distribution of normalized vowel durations in target words with respect to the vowel length according to the original text, i.e., the L2 speakers' intent. The measured data is divided into (a) the so called non-i-vowels (i.e., all the vowels except i-vowels) and (b) i-vowels, as considerable differences between these groups were expected (see 1.2). Additionally, within i-vowels, the data is split according to the letter *i/í* or *y/ý* used in text because, as opposed to L1 Czech speakers, differences in L2 Czech speakers' pronunciation may be expected. The position of vowels within a word (first syllable, second syllable) is distinguished.

Figures 2c, 2d depict distribution of normalized vowel durations and their division into S/L groups as perceived by L1 Czech listeners. The data consists of all the listeners' single judgements. The non-i-vowels/i-vowels division and the position within a word are considered.

The distributions of duration with respect to the two aforementioned aspects, i.e., the L2 speakers' intent and L1 Czech listeners' perception, are compared. Distributions of non- i-vowel duration in the first syllable (Fig. 2a and Fig. 2c, top) indicate two

visible peaks distinguishing S and L vowels in both groups, i.e., L2 speakers and L1 listeners; however the overlap of S and L vowels is lower in L1 Czech listeners (Fig. 2c). Second syllable vowel duration as perceived by L1 Czech listeners (Fig. 2c, bottom) features a similar pattern, although with a greater overlap; the peak of short vowels is shifted to lower durations by comparison with the first syllable, i.e., the duration of short vowels in the second syllable is lower than in the first one. The S and L durations in the production of L2 speakers (Fig. 2a, bottom) overlap substantially.

In the distribution of i-vowel (i, í) duration (see Fig. 2b), there are visible overlaps in L2 Czech speakers, however, one obvious peak indicating S vowels is present, both in the first and second syllables, opposite to L vowels appearing especially in the second syllable. On the contrary, the distribution of the duration of y/ý-words contains two clearly distinguished peaks for both S and L vowels in the first syllable, although its extension does not cover the entire range, i.e., their duration is lower. The originally S vowel *y* is extended as a band over the entire range. The distribution of i-sound in the second syllable, as perceived by L1 Czech listeners, is also outlined as a band with only some traces of hills. Regarding the i-sound in the first syllable, peaks distinguishing S and L vowels are clearly recognizable, but they are close together with a large overlap, as opposed to the first syllable of non- i-sound in L1 Czech perception.

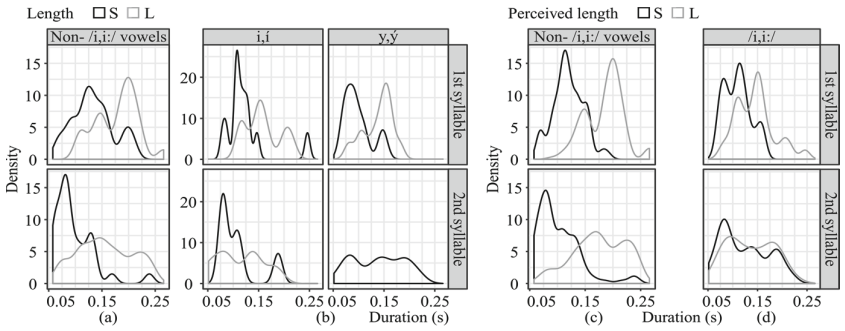

Fig. 2. (a), (b) Distribution of normalized vowel durations realised by L2 speakers split into S/L groups as written in the original text (i-vowels distinguished by the letter used in text). (c), (d) Distribution of normalized vowel durations split into S/L groups as perceived by L1 Czech listeners (without additional division according to the perception experiment setup).

The duration values of short/long vowels overlap is in accordance with the finding [2] that the canonically long vowels are often realized as half-long in Czech of L1 Russian speakers. L1 Czech listeners identified the half-length in both cases: as lengthening of a canonically short vowel and as the insufficient length of a canonically long vowel. For native Czechs, the clearer perceptual distinction between short and long vowels is in line with the findings of [8], who found that listeners with a mother tongue in which the vowel length is phonological have a more categorical perception of this phenomenon than speakers with a mother tongue containing long vowels but without a phonological status (similar finding in [1]).

For each speaker, the differences of F1 and F2 between short /i/ and long /i:/ were evaluated. With respect to the vowel length in the text, L2 speakers' mean difference of F2 (/i:/ minus /i/) is 116.8 ± 114 Hz (significance level $\alpha = 0.05$), and difference of F1 is −37.7 ± 27.8 Hz (i.e., for /i:/, F2 is increased and F1 is decreased according to /i/, with one boundary of confidence interval very close to 0 Hz in both F1 and F2).

Differences of L1 Czech listeners' split between the short and long perception of i-vowels are as follows: L2 speakers' mean difference of F2 (/i:/ minus /i/) is 270.0 ± 115.7 Hz, and difference of F1 is −47.9 ± 34.1 Hz. The relatively frequent shift of the original *mýlí>myli* or *výrů>virů* can be explained by the possible insufficient quality of the first vowel regardless of its duration.

Figure 3 depicts durations of manipulated vowels in perception experiment 2 identified as short or long by L1 listeners. The 50% intervals of values for short and long vowels are clearly different and, moreover, they do not approach each other at all. This again supports the categorical perception mentioned above. As for the first and second syllables, the 50% intervals show no difference; the mean values for long vowels are only shifted further from each other. This corresponds to the fact that in Czech difference in length between stressed and unstressed syllables does not exist. These findings are confirmed also by the duration ratios: the mean ratio of the phonologically same vowels regarding their length is identical and is equal to 1; the long:short vowels mean ratio is identical regardless of their order within a word (SL and LS patterns) and is equal to 2.

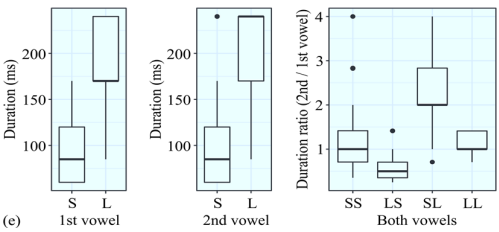

Fig. 3. Durations and duration ratios of short and long vowels in perception experiment 2 as evaluated by L1 Czech listeners.

4 Conclusions

In this paper, the perception of vowel length in L1 Czech listeners based on L2 Czech speech (L1 Russian and Ukrainian) was examined. In ambiguous contexts, the disyllabic target words with controlled S/L pattern (four variants) were miscomprehended in 52.7% assessments. The confusion appeared even in the items evaluated as accentless. The LS pattern showed the greatest agreement between L2 speakers' intent and L1 listeners (72.4%); the lowest agreement was achieved in SL and LL patterns. It was the LS pattern that was the most frequent pattern indicated within the judgements not corresponding to the L2 speakers' intent (59.0%). This most preferable LS pattern is in

accordance with the generally observed tendency of Russian and Ukrainian speakers to produce a long vowel in the stressed syllable, even in the position of canonically short vowel.

The common confusion of short and long vowels in L2 speakers was confirmed by duration measurement as well; the values showed considerable overlap. The data indicates that categorical perception is typical of Czech speakers and the duration of vowels is an essential factor in determining phonological length; however, the perception of vowel length may be influenced by other features, such as quality of vowels.

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