PHRASE-FINAL LENGTHENING OF PHONEMICALLY SHORT AND LONG VOWELS IN HUNGARIAN SPONTANEOUS SPEECH ACROSS AGES

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Abstract
Phrase-final lengthening may concern the vowels or the consonants of the phrase-final syllable, or the whole syllable. Vowel quantity as a phonemic distinction was also shown to interact with phrase-final lengthening. In this study we sought to explore temporal patterns of phrase-initial, phrase-medial and phrase-final, phonemically short and long vowels ([ɔ], [aː]) in words with diverse numbers of syllables focusing on possible differences between Hungarian-speaking young and old subjects. Spontaneous narratives of 10 young and 10 old speakers were randomly selected from the BEA database. Both phonemically short and long vowels were significantly longer in phrase-final positions than in phrase-medial positions in both age groups. Durations of vowels in phrase-medial positions were significantly shorter than those occurring in phrase-initial positions in young speakers' speech while there were no differences in their durations between the two positions in old speakers' speech. All speakers preserved the durational differences in all positions to avoid violating the phonemic patterns of the vowel system. Word length had a significant effect on vowel durations.

Keywords: lengthening, spontaneous speech, [ɔ] and [aː] vowels, young and old speakers

1 Introduction

Phrase-final lengthening is a phenomenon that has been known in phonetics for several decades (e.g., Lindblom, 1968). For definition, the last syllable of the word is lengthened in a phrase-final position, at a prosodic boundary or before a phrase-final pause resulting in longer duration than that of a segmentally identical phrase-medial syllable. More than forty years ago Klatt, one of the first researchers of the topic, claimed that syllables or part of them were longer at the end of the sentences than those occurring in the middle of the sentences (1975). The phenomenon has been reported, on the basis of controlled experiments, to exist in various languages, irrespective of their typological and prosodic patterns, but also to show specific differences across languages (e.g., Beckman, 1992; Fletcher, 2010; Cho, 2016). Phrase-final lengthening has been confirmed

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in numerous languages, for example in English (Turk & Shattuck-Hufnagel, 2007), Estonian (Krull, 1997; Plüschke & Harrington, 2013), Spanish (Oller, 1973; Rao, 2010), German (Kohler, 1983), as well as in Eskimo, Yoruba (Nagano-Madsen, 1992), Hebrew (Berkovits, 1993), Dutch (Cambier-Langeveld, 1997), Arab (de Jong & Zawaydeh, 1999), Chinese (Lee et al., 2004), Finnish (Nakai et al., 2009), Russian (Kachkovskaia, 2014), Japanese (Den, 2015), Chicasaw (Gordon & Munro, 2007); etc. Durational changes may concern the vowels or the consonant(s) of the phrase-final syllable, or the whole syllable (e.g., Berkovits, 1993; Turk, 2007; Dimitrova & Turk, 2012).

Diverse methods relating to subjects, speech materials and procedures can be found in the literature analyzing the phenomenon. The speech materials varied from diverse types of read speech (meaningless sound-sequences, words, sentences) to various types of spontaneous speech samples (narratives, conversations). Phrase-final lengthening has been studied in the speech of adults, children, bilinguals and in language learners' speech samples (both in their L1 and L2) as well as in the case of atypical speakers and even in motherese (Snow, 1994; Lieshout et al., 1995; Gerken, 1996; Baum, 1998; Byrd, 2000; Koponen & Lacerda, 2003; Hansson, 2003; Dankovičová et al., 2004; Byrd et al., 2006; Adam, 2014; Maastricht et al., 2016; etc.). Acoustic-phonetic analysis concern the final syllables, final segments, syllables and/or segments in various other phrasal positions (e.g., Cambier-Langeveld, 1997; Fougeron & Keating, 1997; White, 2002; Kachkovskaia, 2014), and apart from durational measurements, prosody has also been considered in various types of analysis (Wightman et al., 1992; Berkovits, 1994; Hofhuis et al., 1995; Cambier-Langeveld, 1997; Frota et al., 2007; Turk & Shattuck-Hufnagel, 2007; Frota, 2016).

Several factors are suggested that might trigger the lengthening of vowels like subglottal pressure, decreasing articulation activity, some kind of relaxation of articulation gestures, linguistic, phonological, and higher-level factors, as well as syntactic structures, syllable structures, local tempo modifications, speech melody effects, stress patterns, speech rhythm, etc. (e.g., Den, 2015). Some explanations focus on specific cognitive factors like speech planning strategies of the speaker, conscious boundary marking, or the disambiguation of the ambiguous sentences.

In Hungarian, a number of studies have dealt with the temporal properties of the phrase-final lengthening. The existence of the phenomenon was reported both in read (e.g., Kassai, 1982; White & Mády, 2008; Gósy & Krepsz, 2017a) and in spontaneous speech (Hockey & Fagyal, 1999; Markó & Kohári, 2015; Gósy, 2017; Krepsz, 2017). Results confirmed that phrase-final lengthening was more pronounced in spontaneous speech than in reading (Markó & Kohári, 2015). Since the vowel inventory of Hungarian contains vowel pairs distinguished by length (Siptár & Törkenczy, 2000), the question arose whether

speakers regulated their pronunciation in phrase-final syllables considering the phonemic quantity differences of vowels. Four pairs of vowels were selected in a study (Gósy & Krepsz, 2017b) that differed in phonemic length ([o], [oː], [i], [iː] vs. [ɔ], [aː], [ɛ], [eː]), the latter two pairs differed also in terms of vowel quality. Their durational differences were analyzed in phrase-initial, phrase-medial and phrase-final positions across increasing numbers of syllables of the words in read sentences Vowels were significantly longer in sentence final as opposed to medial positions, but no significant differences were found in the durations between initial and final positions. Although phonologically long vowels were significantly longer than phonologically short ones in all positions, sentence-final lengthening was more marked in the phonologically long than in the phonologically short vowels.

Two pairs of vowels differing phonemically ([o], [oː], [i], [iː]) were analyzed in spontaneous speech with the participation of young Hungarian-speaking subjects (Gósy, 2017). In addition, the durations of pauses following the phrase-final syllables were also analyzed. Results supported the previous findings with read sentences that vowels in phrase-final positions were significantly longer than those in phrase-medial positions. Vowels preserved the physical manifest-tations of their phonemic length differences in all phrasal positions, irrespective of vowel quality. Lengthening in phrase-final positions did not yield different ratios depending on phonemic length. There were, however, no interrelations in the durations of phrase-final vowels and the following pauses.

Finally, temporal patterns of syllables and consonants produced in phrase-final positions were analyzed compared to those occurring in phrase-initial and phrase-medial positions (Krepsz, 2017). Results showed that phrase-final length-ening exists not only in the case of vowels but also in that of consonants, and also for the whole syllable. The extent of the lengthening is heavily influenced by the quality of consonants and their position in the syllables. Since Hungarian is an agglutinating language with rich morphology, word length was also consid-ered in the analyses. The number of the syllables of the words was shown to have an effect on the segment and syllable durations in various phrasal positions.

In sum, research results concerning phrase-final lengthening and temporal patterns in Hungarian have confirmed that (i) the phenomenon exists both in read and spontaneous speech, (ii) phonemic length differences are preserved in physical durations in all phrasal positions, (iii) phrase-final lengthening concerns vowels, consonants and the whole syllable produced before pauses, and (iv) the number of the syllables of the words influences the extent of lengthening.

Age is acknowledged to be of considerable importance when speech is considered. Numerous studies have shown the effects of aging on various processes of speech production (Torre–Barlow, 2009). Age-related changes to speech are attributed to changes in the anatomy and physiology of the speech

mechanism, reduced auditory feedback, decreased accuracy of motor control, as well as modified psychic and cognitive functions (e.g., Liss et al., 1990; Wohlert & Smith, 1998; Degrell, 2000; Czigler, 2003; Xue & Hao, 2003; Burke & Shafto, 2004; Zraick et al., 2006; Torre–Barlow, 2009; Rodríguez-Aranda & Jakobsen, 2011).

The chronological age of 65 years is widely accepted as the beginning of the 'elderly' or 'older period of life' (see WHO proposal: www.who.int/healthinfo/survey/ageingdefnolder/en/). However, 'elderly', as an umbrella term, covers diverse periods and thresholds according to ages. In general, subjects of about 50 years of age are identified as middle-aged or pre-elderly while those falling between 60 and 74 years are called young-old. Subjects with ages between 75 and 90 years are the old-old people, and those older than 90 years are the oldest old or very old. The periods themselves show overlaps and shortcomings in referring naturally to a great variety of people of the same and similar ages. Aspects of chronological, biological, psychological, and social ages influence the age categories.

The age of a speaker can be predicted with fair accuracy by her/his speech properties including voice tremor, pitch, speaking rate, loudness, and fluency, etc. (Yorkston et al., 2010). With advancing age, speech changes in the accuracy of articulatory movements, fluency, and communicative effectiveness. The typical process of getting old has a natural effect on breathing, intensity of musculature used during speaking, articulation movements, the effectiveness of speech motor control, and planning of verbal utterances from several aspects (e.g., Enright et al., 1994; Berry et al., 1996; Bashore et al., 1998). A slowing of nerve conduction velocities in the peripheral nervous system and a decrease of central neurotransmitters is supposed to account for a general slowing of articulation in old speakers (Weismer & Liss, 1991). Although verbal communication experience of the elderly can play a role in speaking in old ages, there is also evidence that a general mechanism limits elderly speakers' speech performance.

Based on findings in the literature we can conclude that there are pronounced age differences in the timing of speech in pre-elderly and old speakers (e.g., Kail & Salthouse, 1994). Investigations confirmed that elderly speakers adjust the length and durational patterns of their utterances according to their physiological capacity (Winkworth et al., 1995). Old people's speech tempo was significantly slower than those of young speakers', they produced significantly shorter speech samples and slower articulation than young speakers did (Amerman & Parnell, 1992; Huber, 2008; Jacewicz et al., 2010; Bóna, 2012). Word durations of elderly people were reported to be significantly shorter than those of young speakers, while speech sound durations produced by old speakers were remarkably longer than those of young ones (Smith et al., 1987; Bóna, 2012, 2013; Kent, 2000; Fletcher & McAuliffe, 2015).

However, speech timing control of old speakers was shown to be the same as that of young speakers in temporal adjustments of consonant articulation according to consonant duration and vowel distance (Amerman & Parnell, 1992). Similar findings were reported on temporal patterns of VOTs produced by young and elderly people (Sweeting & Baken, 1982). Although no significant differences were found in VOT values between young and old speakers, variability of the data increased with age, both within subjects and between groups. Age did not appear to influence accuracy of temporal parameters in lip and jaw tracking (Ballard et al., 2001). Speech motor control exhibits inherent temporal properties of speech production, where some subprocesses and/or some local temporal organization may remain intact in aging, may be somewhat resistant to aging effects, or may employ specific strategies in old age (Brenk et al., 2009).

To our knowledge, few investigations were devoted to analysing phrase-final lengthening in the elderly. Swedish-speaking young (ages between 20 and 30 years) and old (ages between 55 and 75 years) speakers' spontaneous speech samples were examined according to the temporal patterns of phrase-final lengthening (Hansson, 2003). Findings showed no differences in the lengthening patterns depending on age. Speakers of the Chicasaw language were over 60 years old when their speech samples were examined, and they showed clear phrase-final lengthening according to their language specificity (Gordon & Munro, 2007). Studies on phrase-final lengthening in aphasic speech report data also of age-matched elderly controls where the latter show the phenomenon in contrast to aphasic patients (e.g., Hammond, 1990).

The question is whether the age of Hungarian-speaking adults is a decisive factor in phrase-final lengthening. How do old Hungarian speakers implement phonemic length differences and different word lengths when realizing phrase-final vowels as opposed to their realizations in initial and medial positions in spontaneous speech? Are there any differences in the elderly's temporal patterns when compared to those of young speakers? Do old speakers regulate utterance-final lengthening to preserve the phonemically relevant quantity of vowels? How do phrasal positions and word lengths influence the temporal patterns of vowels produced by old speakers? In this study, we seek to explore temporal patterns of phrase-initial, phrase-medial and phrase-final, phonemically short and long vowels ([ɔ], [aː]) in words with diverse numbers of syllables focusing on possible differences between young and old speakers. No one has analyzed phrase-final lengthening in Hungarian elderly speakers' speech so far.

Five hypotheses were formulated. (i) Phrase-final lengthening will preserve the phonemic quantity differences of the target vowels irrespective of the speakers' age, (ii) phrase-final lengthening would be less expressed in the old age than in the young, (iii) target vowels will not show durational differences in phrase-initial and phrase-medial positions in old speakers' speech, (iv) the

number of syllables of the words will influence the durations of the target vowels occurring in phrase-final positions, and (v) the length of words will have a greater effect on vowel durations as produced by old speakers than on those of young speakers.

2 Methodology

Spontaneous narratives (more than 9 hours' material) of 10 young subjects (aged between 20 and 30, mean: 25 years) and 10 old ones (aged between 70 and 80, mean: 75 years) were randomly selected from the BEA Spontaneous Speech Database of Hungarian (Gósy, 2012). The topic of the narratives was the same with all subjects, they spoke about their (past) jobs, families, everyday activities, hobbies. Each group consisted of an equal number of females and males. Speakers of the database spoke the Budapest dialect of Hungarian. Articulation and hearing were age-appropriate with all subjects, they did not encounter any articulation disorder or specific hearing loss.

A phonemic pair of short and long vowels ([ɔ], [aː]) was selected as target vowels (they are, however, different in tongue height and lip rounding). For this study, 3,672 vowels were segmented, of which 2,250 were phonologically short and 1,422 were phonologically long vowels. Young speakers produced 1,672 vowels while 2,000 vowels were produced by old people. The vowels occurred in phrase-initial (1,034 tokens), phrase-medial (1,412 tokens) and phrase-final positions (1,226 tokens) in the last syllables of the words (either in stems or in suffixes). Words varied according to their lengths, from disyllabic words to 6-syllable ones. Occurrences in stems and suffixes were very similar for both vowels and in all positions. Young speakers produced 283 short and 265 long vowels while old speakers produced 274 short and 211 long vowels. Both content words and function words were considered. Special attention was paid to the occurrences of the target vowels according to their phonemic length, the three phrasal positions, the number of syllables the words consisted of, and the ratios of stems and suffixes that contained them. All syllables containing the target vowels were unaccented irrespective of their phrasal positions.

The same target vowels as occurring in monosyllables were analyzed separately as a kind of control set. Altogether 1,033 such vowels were considered, of which 557 were phonologically short and 476 were phonologically long vowels.

Examples for [ɔ] (in orthography *a*) vowels both in stems and in suffixes (target vowels are written in bold, the abbreviation SIL stands for silence):

(1) SIL *magy**a**r szakra járok bár mostanában már úgy mesélem hogy alkalmazott nyelvészetre* SIL
'I study Hungarian language and literature though presently I say applied linguistics';
(2) SIL *ezzel a kiegészítéssel készen lesz a diplom**a*** SIL
'the thesis will be ready with this supplement';

(3) SIL *tudn**a**k tájékozódni három dimenzióban segítség nélkül* SIL
'they can orient themselves in all three dimensions without any help';
(4) SIL *akkor könyvkiadóban dolgozt**a**m és korrektori munkát végeztem* SIL
'I have worked in a publisher's office as a proof-reader'.

Examples for [a:] (in orthography *á*) vowels both in stems and in suffixes:

(5) SIL *a bar**á**t fontos minden gyereknek* SIL
'a friend is important for all children';
(6) SIL *sokan vannak akik dolgoznak de otthagyták mert ez a fajta ir**á**ny* SIL
'there are many people who are working [beside their studies] but they quit because this kind of way' SIL;
(7) SIL *a béték**á**n* [Bölcsészettudományi Karon] *magyar szakra járok* SIL
'I study Hungarian as my major at the ELTE university';
(8) SIL *arra gondoltam hogy ez a kirándul**á**s* SIL
'I have been thinking that this excursion'.

The speech material has been manually annotated by the two authors separately according to phrases (periods between two pauses), words and target vowels with simultaneous visual feedback in Praat software (Boersma & Weenink, 2015). The target vowels were segmented by defining the interval between the onset and offset of the second formants of the vowels. Segmentation was checked by a third phonetician (in case of disagreement, which was less than 1%, the vowels in question were excluded). A specific script was written for obtaining the values automatically. Examples for [a:] vowels in phrase-initial, phrase-medial and phrase-final positions produced by a male speaker are shown in Figure 1.

Durations of the vowels were analyzed according to (i) vowel quality, (ii) word length, (iii) phrasal position, and (iv) the speaker's age.

The distribution of the data were normal in both ages and in both vowels according to the Kolmogorov–Smirnov test (using SPSS 15.0 software). To test statistical significance, General Linear Mixed Models analyses were carried out to test the effects of the fixed factors *position, vowel quality, word length, age,* and their interactions on durations of the vowels (dependent factors). The confidence level was set at the conventional 95%.

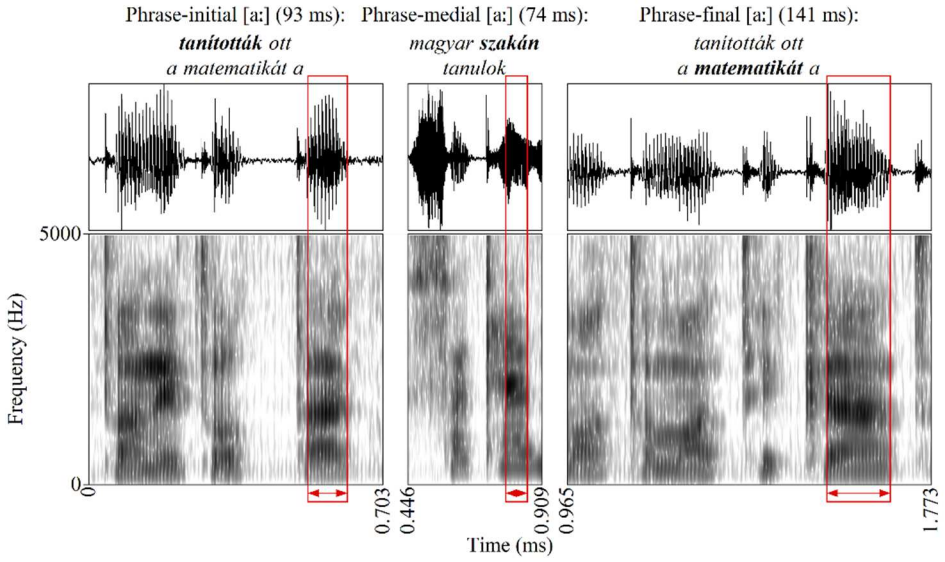

Figure 1.
Annotated samples of utterances containing the vowel [a:] in phrase-initial, phrase-medial and phrase-final positions (bold letters identify the carrier words of the target vowels)

3 Results

There will be two parts of the analysis in relation of the temporal patterns of the target vowels produced by both the young and old speakers. In the first part we will focus on the vowels that occurred in polysyllabic words while the other part is engaged with the vowels that occurred in monosyllables.

The presentation of the data will gradually and selectively be extended according to the factors that influence the durations of the target vowels as Figure 2 demonstrates. The data of the physical durations of the phonemically short and long vowels will be presented first. The next step concerns the distribution of the data according to the phrasal positions followed by extending the durational data of young and old adults, separately, on the one hand, and of the phonologically short and long vowels, separately, on the other. The next approach contains the data of the vowels' durations in the three phrase positions, distributed according to age and phonological length. The durational data according to word length are presented in relation to (i) phonological length, (ii) age, and (iii) interrelations of the two. Finally, the measured durations of the target vowels will be shown according to the phonological length of the vowels, the age of the speakers, the three phrasal positions and word length. Durational data of the target vowels occurring in monosyllables complete the presentation of the results.

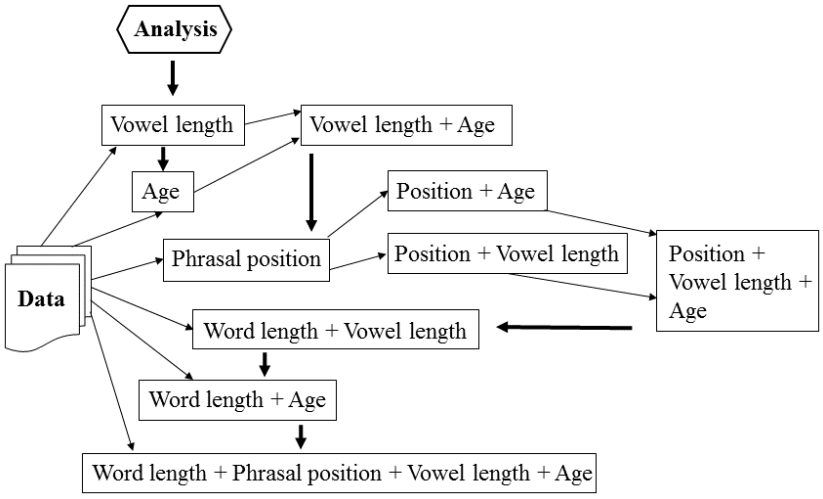

Figure 2.
Schematic process of the data analysis according to the factors involved

Different phonemic durations of [ɔ] and [aː] vowels are reflected by different durational values produced by both the young and old speakers (Figure 3).

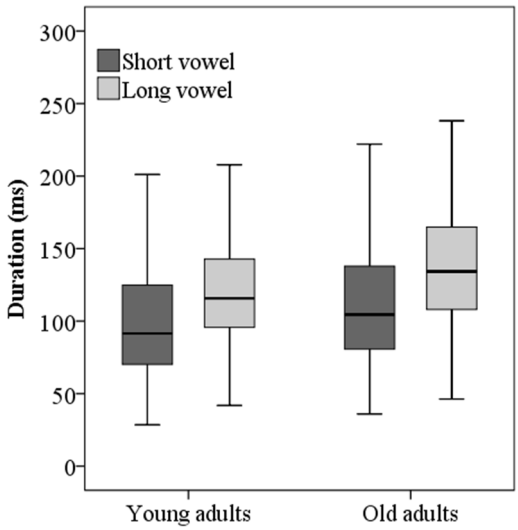

Figure 3.
Durations of the vowels analyzed as produced
by young and old speakers (medians and ranges)

Measured durations of [ɔ] vowels were significantly shorter than those of [aː] vowels. Mean durations of phonemically short vowels turned out to be 100 ms in

young and 113 ms in old speakers while those of phonemically long vowels were 123 ms in young and 139 ms in old speakers. The differences between the short and long vowels were significant in both age groups (for young speakers: $F(1, 1671) = 22.157$; $p = 0.011$; for old speakers: $F(1, 1999) = 17.844$; $p = 0.008$). In addition, the durational differences between the young and old speakers were also shown to be significant (for [ɔ] vowels: $F(1, 2249) = 22.157$; $p = 0.011$; for [aː] vowels: $F(1, 1421) = 22.157$; $p = 0.011$).

Vowel durations were analyzed according to the positions of the words in the utterance where they occurred in the last syllables of the words. Both phonemically short and long vowels were significantly longer in phrase-final positions than either in phrase-initial or phrase-medial positions irrespective of age groups (Figure 4). Values of all speakers confirmed the phenomenon of phrase-final lengthening in the cases of all vowels irrespective of their phonemic length. Durations of the vowels in phrase-medial positions (mean: 99 ms) were significantly shorter than those occurring in phrase-final positions (mean: 146 ms). Vowel durations were shorter in phrase-initial positions (123 ms) than in phrase-final but longer than in phrase-medial positions. Statistical analysis confirmed that position had a significant effect on the durations of the vowels ($F(2, 3670) = 51.389$; $p < 0.001$).

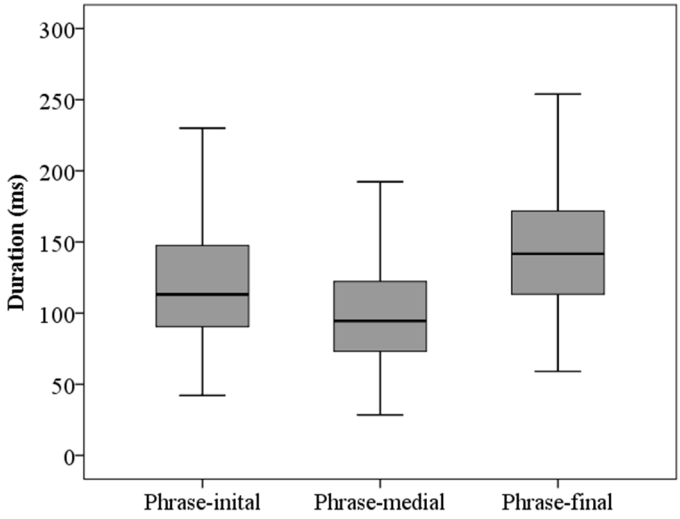

Figure 4.
Durations of the vowels analyzed in phrase-initial, phrase-medial and phrase-final positions (medians and ranges)

Durations of the vowels in the three phrase positions showed similar patterns produced by both young and old speakers (Figure 5). The mean duration of the vowels in phrase-initial position was 106 ms in young and 135 ms in old speakers, while the mean values were 100 ms and 98 ms, respectively, in phrase-medial positions. They turned out to be shorter than those occurring in phrase-final positions produced by young (mean: 142 ms) and by old speakers (147 ms). Statistical analysis confirmed that vowel durations were significantly different depending both on position and age (for young: $F(2, 1671) = 29.403$; $p = 0.014$; for old: $F(2, 1999) = 26.005$; $p = 0.018$).

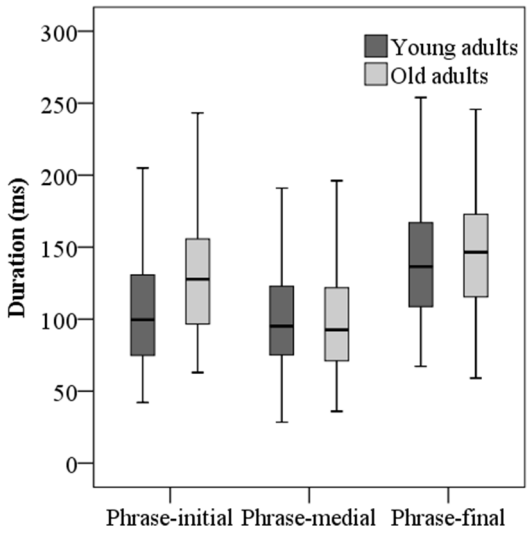

Figure 5.
Durations of the vowels analyzed in phrase-initial, phrase-medial and phrase-final positions depending on age (medians and ranges)

We analyzed the measured durations of the phonemically different vowels in the three positions but we did not consider the two age groups separately (Figure 6). As expected, the durations of the phonemically different vowels are similar across the three positions. Mean duration of [ɔ] vowels was 111 ms in phrase-initial positions, 89 ms in phrase-medial positions, and 138 ms in phrase-final positions. Mean duration of [aː] vowels was 139 ms in phrase-initial positions, 115 ms in phrase-medial positions, and 161 ms in phrase-final positions. The smallest difference in durations depending on the phonemic length of the vowels was found in phrase-final positions (23 ms, on average vs. 26 ms and 28 ms). Statistical analysis confirmed that the durations of both the phonemically short and long vowels are significantly different depending on position (for [ɔ]: ($F(2, 2249) = 11.678$ $p = 0.006$); for [aː]: ($F(2, 1421) = 13.408$; $p = 0.021$).

Data show that old speakers produced both phonemically short and long vowels longer than young speakers did. The mean value of [ɔ] vowels produced by young speakers was 100 ms in phrase-initial position, 89 ms in phrase-medial and 131 ms in phrase-final position. The mean value of the same vowels produced by old speakers was 113 ms in phrase-initial position, 88 ms in phrase-medial and 141 ms in phrase-final position. The temporal values of [aː] vowel produced by young speakers were 121 ms, 113 ms, and 157 ms, respectively while those produced by old speakers were 153 ms, 118 ms, and 165 ms, respectively. There was practically no difference found in the vowel durations between young and old speakers in phrase-medial positions. As expected from the former analyses, the mean durations of the phonemically long vowels indeed exceed all mean durations of the phonemically short ones in the same positions in both age groups (Figure 7). The lines in the figures demonstrate the age-specific differences in the target vowels' durations. Both the phonemically short and long vowels are longer in phrase-initial and phrase-final positions in old speakers than in young speakers, particularly in the intitial positions. However, the durational patterns are almost the same in phrase-medial positions.

Word length had a significant effect on vowel durations. Table 1 contains the durational values of the vowels analyzed, irrespective of position and age. The durations of [ɔ] vowels do not change dramatically according to the number of the syllables in the words. Their durations decrease by 18 and 20 ms between disyllabic words and words containing 5 and 6 syllables. The decrease of the durations of [aː] vowels according to the increasing number of syllables of the words is more remarkable, though the values vary. The temporal difference between phonemically short and long vowels decreases as word length increases (up to 29 ms as the largest difference).

The decrease of vowel durations according to the increasing length of the words can be experienced both with young and old speakers. What is interesting here is the different changes of the values in the two age groups. The durations are longer in old speakers' spontaneously produced words that contain 2, 3 or 4 syllables than the same ones produced by young speakers. However, old speakers' values abruptly shorten in words consisting of 5 and 6 syllables, and become shorter than those produced in the same word length by young speakers (Table 2).

Changes of vowel durations according to increasing word length seem to be in connection with syllable reduction in long words. Durations of the vowels depending on word length turned out to be signifiantly different in both age groups (young speakers: $F(5, 1671) = 30.214$, $p = 0.004$; old speakers: $F(5, 1999) = 19.789$, $p = 0.009$). The observed abrupt shortening in words consisting of 5 and 6 syllables in old speakers resulted in significant temporal differences between these long words and the shorter ones confirmed by post hoc tests (in

the case of 5-syllable words vs. shorter ones: $p = 0.040$, $p = 0.037$, $p = 0.031$, and 6-syllable words vs. shorter ones: $p = 0.032$, $p = 0.042$, $p = 0.021$).

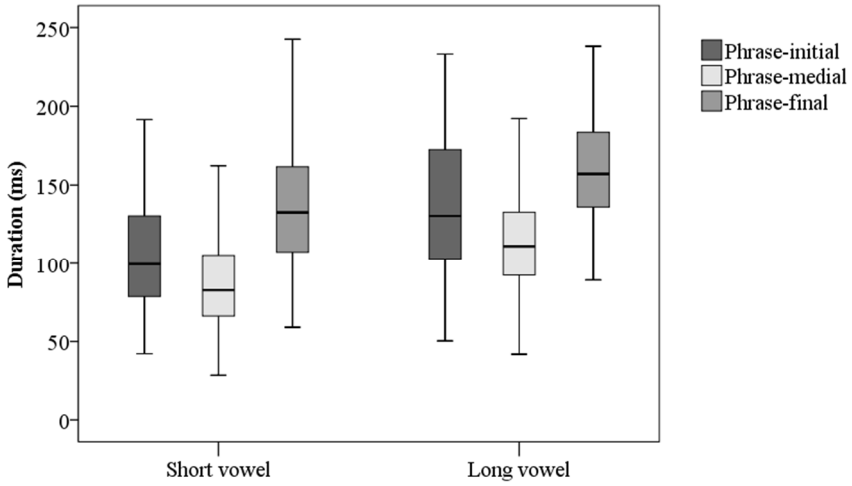

Figure 6.
Durations of [ɔ] and [aː] vowels in phrase-initial, phrase-medial and phrase-final positions irrespective of age (medians and ranges)

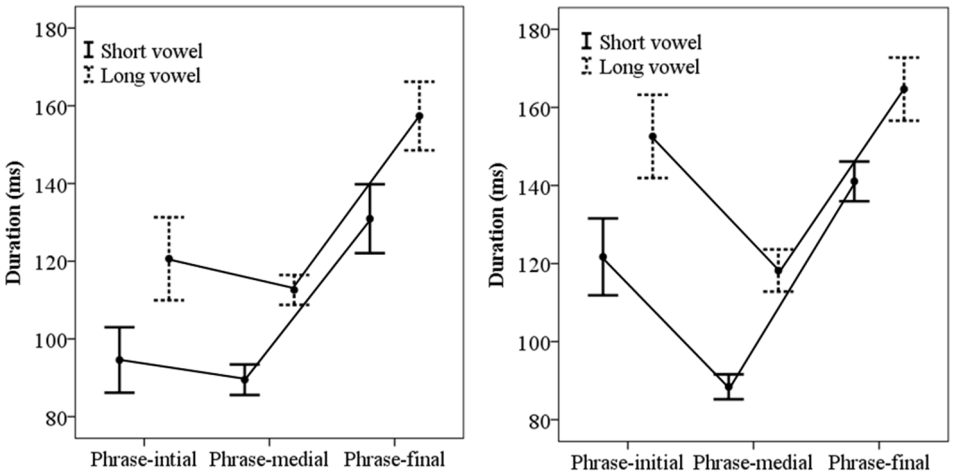

Figure 7.
Durations of the vowels analyzed in phrase-initial, phrase-medial and phrase-final positions produced by young (left) and old (right) speakers (means and ranges). Lines connecting the medians help to differentiate short and long vowels' durations

Table 1. Durations of the target vowels depending on the number of syllables in words (mean ± standard deviation)

Number of syllables in words	Durations of vowels (ms) [ɔ]	[aː]
2	111±40	129±40
3	109±45	133±41
4	103±55	122±39
5	91±38	131±41
6	93±31	104±19

Table 2. Mean durations of the vowels analyzed depending on words length and age of speakers (mean ± standard deviation)

Number of syllables in words	Durations of vowels (ms) young speakers	old speakers
2	112±40	125±41
3	110±42	123±46
4	104±38	116±55
5	107±51	97±35
6	102±32	89±20

Irrespective of phrase position, [ɔ] vowels are produced longer by old speakers than by young speakers with the only exception of the words consisting of 6 syllables. The vowels in these words were longer in the case of young speakers (Figure 8). The range of the vowel durations is wider than in the case of the young speakers, with the exception of the longest words.

Again, irrespective of phrase position, durations of [aː] vowels are similar to those of the phonemically short ones (Figure 9). Shortening of the durations can be seen in vowels produced by both young and old speakers; however, the decreasing tendency is more marked with the old speakers than with the young ones. There is no steep decrease in durational values for [aː] vowels in young speakers' speech. Statistical analysis confirmed that durations of both vowels depending on word length are statistically different in both age groups (see the summary in Table 3).

Finally, the analysis was extended considering all factors (Figures 10 and 11). Vowels were the longest in phrase-final positions, and reductions according to increasing word length are particularly characteristic in this position. The changes in the values are more marked with old speakers than with young speakers. Durations of [ɔ] vowels were the shortest in phrase-medial positions showing larger differences in old speakers' speech than in young speakers' speech. There were no statistically significant differences in durations between the vowels occurring in phrase-initial and phrase-medial positions in young speakers. The same differences in old speakers, however, proved to be significant ($F(5, 1998) = 23.589, p = 0.001$).

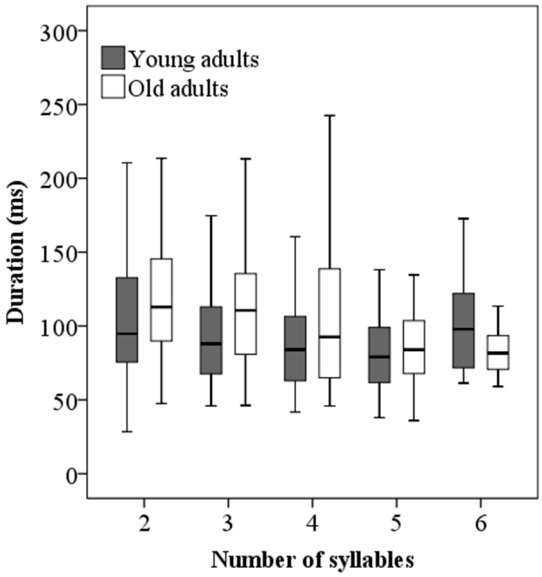

Figure 8.
Durations of [ɔ] vowels depending on word length produced by young and old speakers (medians and ranges)

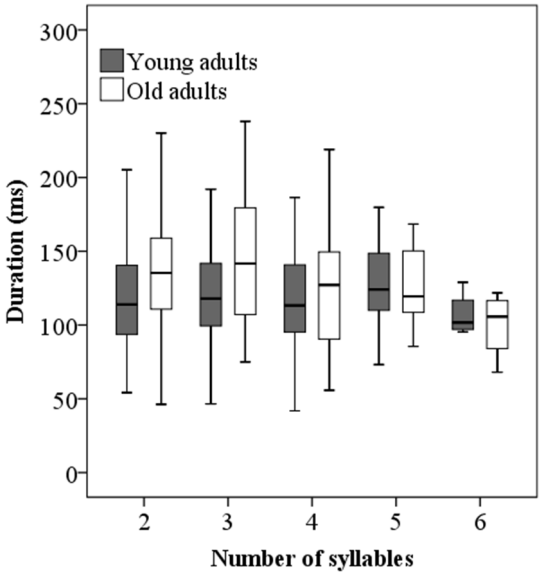

Figure 9.
Durations of [aː] vowels depending on word length produced by young and old speakers (medians and ranges)

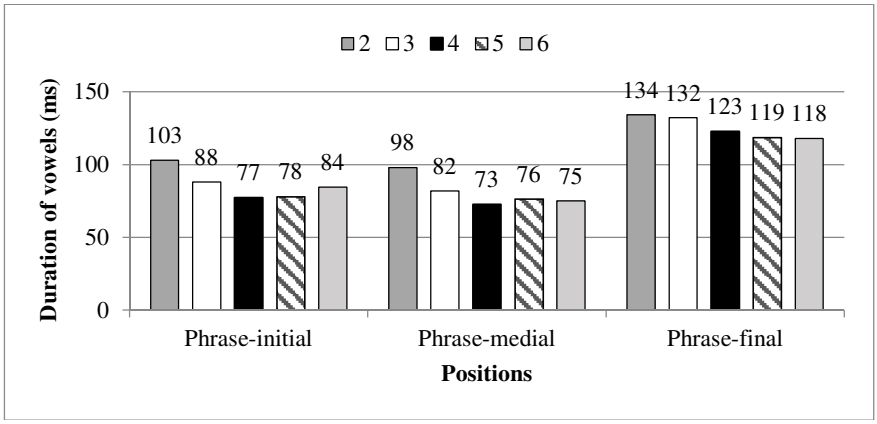

Figure 10.
Mean durations of [ɔ] vowels depending on word length in three positions produced by young speakers

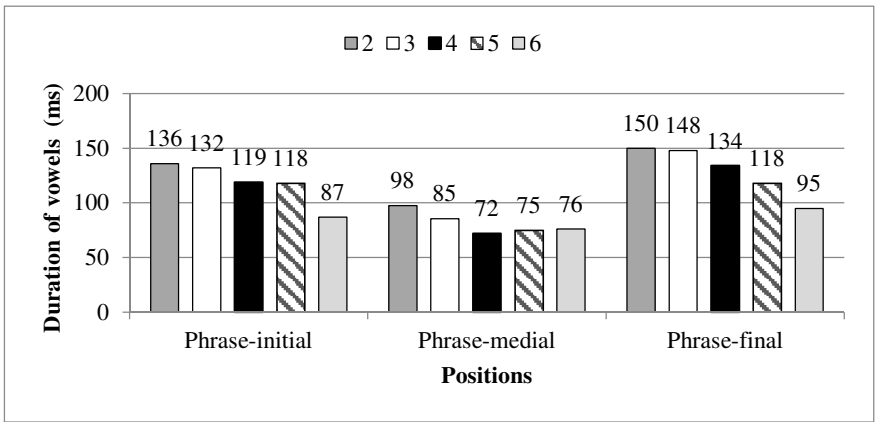

Figure 11.
Mean durations of [ɔ] vowels depending on word length in three positions produced by old speakers

The same analysis was carried out focusing on phonemically long vowels' durations considering words length, phrase position and age (Figure 12 for young and Figure 13 for old speakers). Values of [aː] vowels show similar distribution to what was experienced with phonemically short vowels. Vowels were longer in phrase-final positions than in phrase-medial positions in both age groups; however, durational patterns are different when considering all phrase positions. There were no statistically significant differences in durations of vowels occurring in phrase-initial and phrase-medial positions in young speakers' speech. On the contrary, it was between phrase-initial and phrase-final

positions that no significant differences were found in vowel durations in old speakers' speech.

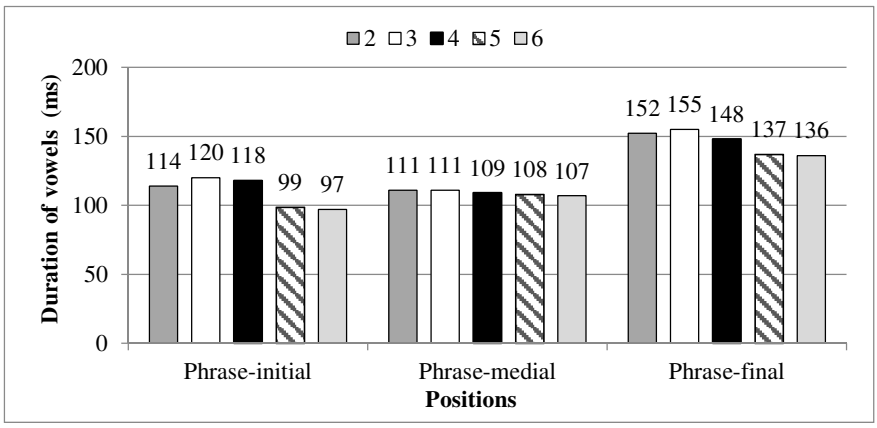

Figure 12.
Mean durations of [a:] vowels depending on
word length in three positons produced by young speakers

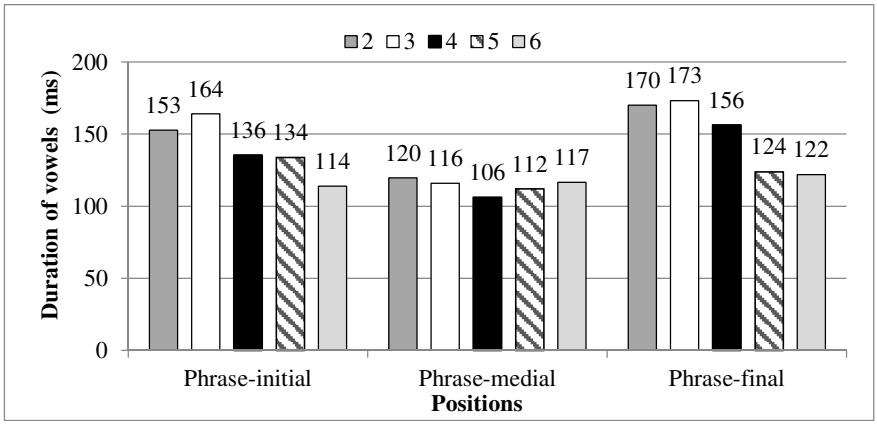

Figure 13.
Mean durations of [a:] vowels depending on
word length in three positions produced by old speakers

Results of the statistical analysis of the temporal patterns and their interactions for the vowels produced in polysyllabic words are summarized in Table 3. (The results of the detailed statistical analysis are given in the text.)

Table 3. Statistical data of the durational patterns of the vowels analyzed, as occurring in polysyllabic words (the value of df2 is 3.671 in all cases)

Factors	**df1**	***F*-value**	***p*-value**
position	2	51.389	< 0.001
vowel quality	1	88.932	< 0.001
word length	4	7.336	< 0.001
age	1	10.934	0.001
positon * word length	8	2.481	0.006
position * age	2	12.967	< 0.001
vowel quality * word length	4	7.762	< 0.001
position * vowel quality * age	2	6.676	0.001
vowel quality * word length * age	4	3.426	0.004
position * vowel quality * age * word length	6	3.341	0.002

3.1 Temporal patterns of monosyllables

Monosyllables are characteristically longer than the syllables of polysyllabic words (e.g., White & Mády, 2008; Gósy & Krepsz, 2017a). Therefore, it is expected that vowels of monosyllables should also be longer than those occurring in longer words. In addition, all monosyllabic content words have word stress (at least theoretically), while the syllables we measured in this study so far have definitely no perceivable lexical stress (according to the authors' judgement). Considering all these facts, we decided to pay special attention to vowel durations occurring in monosyllables in both age groups, and analyzed them separately from those in polysyllabic words. Table 4 summarizes the descriptive data.

All phonemically long vowels produced by both the young and old speakers were significantly longer than the phomemically short vowels. All vowels produced by old speakers were significantly longer than those produced by young ones. Phonemically short vowels produced both by young and old speakers show quasi-regular changes according to phrase positions: those occurring in phrase-medial positions were the shortest while those occurring in phrase-final positions were the longest. Durations of vowels occurring in phrase-initial positions fall in between (Figures 14 and 15).

Statistical analysis of the target vowels occurring in monosyllables confirmed significant differences in durations of vowels (for young speakers: $F(1, 547) = 27.155$; $p = 0.016$; for old speakers: $F(1, 484) = 19.306$, $p = 0.011$). In addition, phrase position also proved to have a significant effect on durations (young speakers, [ɔ] vowels: $F(1, 282) = 17.033$, $p = 0.018$ and [aː] vowels: $F(1, 264) = 19.345$, $p = 0.017$; old speakers, [ɔ] vowels: $F(1, 273) = 10.414$, $p = 0.021$ and [aː] vowels: $F(1, 210) = 20.686$, $p = 0.012$).

Table 4. Mean durations and standard deviations (mean ± SD) of the target vowels in monosyllables depending on position and age

Position	Mean duration of vowels (ms)			
	Young adults		Old adults	
	[ɔ]	[aː]	[ɔ]	[aː]
phrase-initial	95±64	117±26	148±81	176±45
phrase-medial	89±50	96±29	139±78	151±56
phrase-final	136±67	151±33	181±59	205±51

Temporal patterns of both the phonemically short and long vowels in monosyllabic and polysyllabic words are similar in young adults. The mean values of the short vowels are longer in monosyllables than those occurring in polysyllabic words; however, no differences were found between them occurring in phrase-medial positions. Durations of phonemically long vowels are longer in polysyllabic words in all positions although the differences are not large in all cases. The temporal differences of the target vowels between phrase-medial and phrase-final positions are more marked in monosyllables than in polysyllabic words in young adults.

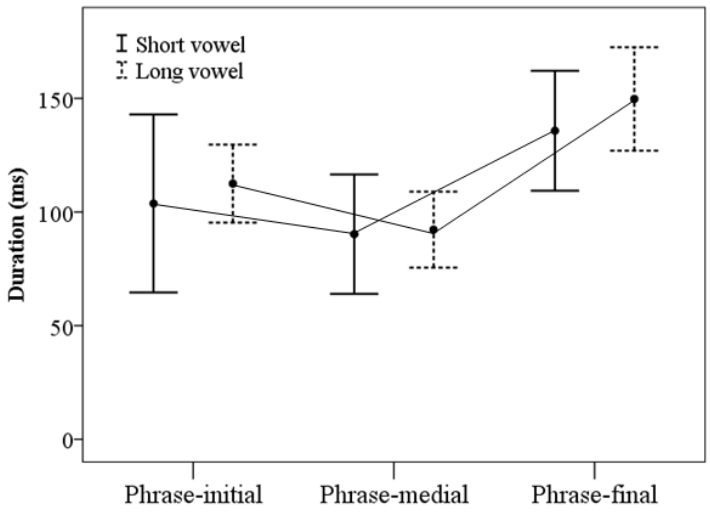

Figure 14.
Durations of the target vowels that occur in monosyllables depending on phrase position in young speakers (means and ranges)

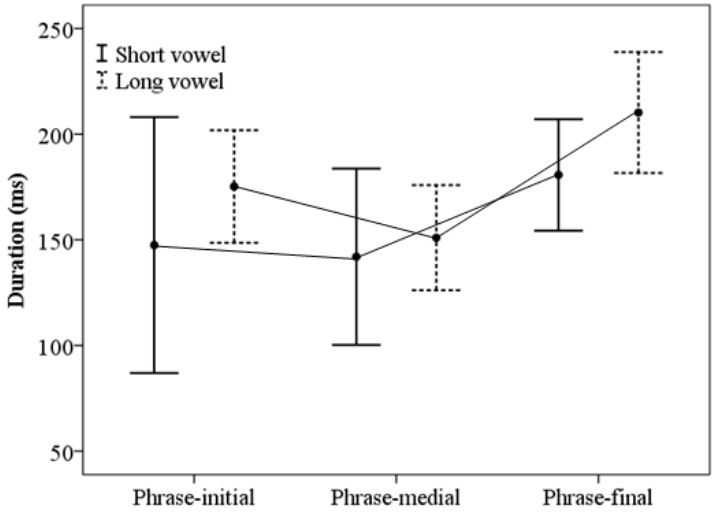

Figure 15.
Durations of the target vowels that occur in monosyllables depending on phrase position in old speakers (means and ranges)

The durational values of the target vowels produced by old speakers are longer in monosyllables than in polysyllabic words without exception. Phrase-final lengthening is more marked in phonemically long vowels in monosyllables while it is more marked in phonemically short vowels in polysyllabic words. The strength of phrase-final lengthening (expressed in longer durations compared to phrase-medial position) seems to be different depending on age.

4 Conclusions

Several questions were raised concerning phrase-final lengthening in spontaneous speech, in view of the agglutinating nature of Hungarian. We wanted to obtain evidence for (i) phrase-final lengthening using two vowels differing in phonemic quantity ([ɔ], [aː]), (ii) preservation of the target vowels' phonemic quantity in phrase-final positions, (iii) the durational differences of the target vowels depending on phrasal positions, (iv) the effect of word length on the target vowels' durations, and (v) the assumed differences in temporal patterns betwen young and old speakers differing by 50 years, on average.

Our results confirmed again – in accordance with the former research results (e.g., Gósy & Krepsz, 2017a) – that utterance-final lengthening does exist in Hungarian spontaneous speech. As expected, both phonemically short and long vowels were significantly longer in phrase-final position than in initial and medial positions irrespective of age. This means that old speakers' production exhibits the same effect on vowel durations in the phrase-final positions as was

observed in young speakers. We can conclude that phrase-final lengthening is a phenomenon that is characteristic of speech (and language) but not of adult age. So, our first hypothesis was confirmed.

Our findings supported the claim that phonemic vowel quantity contrasts are preserved in all phrasal positions, including phrase-final ones. The clear distinction between short and long vowels also in phrase-final positions suggests that speakers avoid violating the phonemic patterns of the vowel system. Speakers preserved the phonological quantity differences of the target vowels in all phrasal positions meaning that the measured durations of the phonologically long vowels were longer than those of the phonologically short ones. So, our hypothesis was also confirmed here. We hypothesized that phrase-final lengthening would be less expressed in the old age group than in the young one. Findings did not support this assumption: Temporal patterns of phrase-final lengthening showed similar tendencies in the cases of both the young and old speakers.

Results showed that significantly different durations were produced by the young and the old speakers. The target vowels of the polysyllabic words were longer in old than in young speakers irrespective of the phonemic length differences of the vowels. This can obviously be explained by the old age: the relatively slow articulation gestures and slow cognitive operations of the old speakers. It has often been noted that older adults used slower speaking rates (e.g., Shipp et al., 1992; Winkler et al., 2003; Bóna, 2013).

Vowels were the shortest in phrase-medial positions and longest in phrase-final positions in both the young and old age groups. However, differences were found in the measured durations between the phrase-initial and phrase-medial positions depending on age. The durational differences of the target vowels in these two positions were less large as produced by young speakers than in those produced by old speakers. We suggest that old speakers seem to signal the phrase-initial position to a larger extent than did the young speakers. The reason behind this temporal difference may be in connection with the old speakers' supposed intention to mark the beginning of their phrases. However, further research can confirm or reject this assumption. We hypothesized that target vowels would not show durational differences in phrase-initial and phrase-medial positions in old speakers' speech. This assumption, however, was not confirmed.

The temporal patterns in relation to the number of the syllables of the words showed similar tendencies in old speakers as it was found with the young participants. The slight differences concern the reduction patterns. The reductions of the vowel durations according to the increasing length of the words showed both increased and decreased mean values in the case of young speakers, particularly in phrase-initial and phrase-medial positions. The reductions are more gradual according to the increasing number of syllables in the words in the case of old speakers, particularly in phrase-final positions. Old speakers scarcely

reduce the vowel durations in the other two phrasal positions. We think that the reduction differences depending on age are in connection with slower articulation and slower high-level operation of speech planning with old speakers. The similar durations of the target vowels in phrase-initial and phrase-medial positions as well as the decrease of durations along with the increase of word length in old speakers' speech is assumed to be the consequences of both their breathing and cognitive processing (Hooper & Cralidis, 2009).

We hypothesized that old speakers would reduce their vowel durations in the phrase-final positions in long words more than young speakers would do. The data supported this assumption in the case of words consisting of 5 and 6 syllables. We suggest that physiological constraints of the old speakers would result in the need of reduced articulation of final vowels of the long words. The question is, however, whether accessing lemmas or the whole phonological forms prior to articulation takes longer time for old speakers that requires in some sort of fast finishing the articulation of the long words. Or, it is just the necessary articulation of 5 and 6 syllables without breaking off as it is possible between two shorter words in connected speech (breathing capacity, control over the structure of the long words, specific articulation strategy of elderly speakers, cf., Brenk et al., 2009).

The target vowels in monosyllables were significantly longer than in polysyllabic words produced by old speakers. This finding can be explained by the different lexical access of short and long words, on the one hand, and by some time gaining behavior of the old speakers they use in the cases of the monosyllables. We suggest that the different temporal patterns of the target vowels depending on phrasal positions between young and old speakers is the result of the old speakers' intention to mark largely the phrasal positions. Old speakers want to be understood more than young speakers do.

We conclude that clear distinction of short and long vowels also in phrase-final positions suggests that speakers avoid violating the phonemic patterns of the vowels irrespective of age. Speech motor control refers to the systems and strategies that control the production of speech (Kent, 2000), and this control works throughout the speaker's lifespan. The temporal patterns analyzed in this research show some age-specific differences along with the preservation of the phonological representations of the target vowels and their physical realizations.

The findings of our research raise further questions on the possible effect of individual speech planning and articulation on the temporal patterns of the phrase-final syllables of words across ages. This requires further investigations.

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