GLOTTAL MARKING IN SENTENCE READING: COMPARISON OF ADOLESCENTS' AND ADULTS' SPEECH PRODUCTION

TEKLA ETELKA GRÁCZI
Research Institute for Linguistics; MTA–ELTE Lendület Lingual Articulation Research Group
graczi.tekla.etelka@nytud.hu

ALEXANDRA MARKÓ
ELTE Eötvös Loránd University; MTA–ELTE Lendület Lingual Articulation Research Group
marko.alexandra@btk.elte.hu
https://orcid.org/ 0000-0003-0301-7134

Abstract

Glottal marking is well described for adult speakers; however, children's speech has been less documented yet. The present study analysed the appearance of glottal marking in 16 adolescent (16- and 17-year-old) and 16 adult (20- to 45-year-old) speakers' reading aloud (with an equal number of males and females in both age groups). Data in terms of gender as well as age were compared based on four parameters of frequency of occurrence. The results showed that although the frequency of occurrence of glottal marking in adolescent speech in general was somewhat lower than in adult speech, and the gender-specific differences did not appear yet, the positional triggers for glottal marking were found to affect the frequency of the phenomenon similarly in the two age groups. The results and further research may contribute to the better understanding of both the appearance of glottal marking and the emergence of gender-specific characteristics of speech.

Keywords: glottal marking, adolescents, adults, sentence reading, Hungarian

1. Introduction

The speech attributes of adolescents are undeservedly underinvestigated in both international and Hungarian phonetic research, despite the fact that this age group represents an inevitable transition between childhood and adulthood. The analysis of adolescent speech may shed light on several developmental issues in both biological and social dimensions. The phonation characteristics of adolescents following the pubertal change of voice may gradually come to serve the same discourse functions which are already well-documented in adult speaking behaviour from boundary marking to the expression of attitudes. The development of correlations between various aspects of voice quality and communicative functions is a topic well worth exploring. The present study provides an analysis of a certain stage of this development based on a study of Hungarian read speech. Our aim is to compare certain features of adolescent and adult speech, namely the frequency and the position of glottal marking in sentence reading.

Phonation results from vocal fold vibration. This vibration is usually quasiperiodic, leading to modal phonation; however, inconsistency may also appear. The phenomenon goes by several names, e.g. *creaky voice, glottalization, vocal fry.* Whichever term is used, it is an umbrella

DOI: 10.5281/zenodo.3907323 ISSN 2732-1142

term, as the vibration can be aperiodic in several ways: the timing or amplitude of adjacent periods may exceed the normal ranges of jitter and shimmer (e.g. Surana–Slifka 2006). Some researchers also analyse the glottal stop in this context (e.g. Dilley et al. 1996). Therefore it is not always clear which terms refer to which types of glottal behaviour, or which terms are treated as synonyms. In our own analysis, we use the term *glottal marking* in reference to both (and together) glottalization and glottal stop.

The functions of glottal marking vary across languages. It can fulfill various roles: phonological (see e.g. Gordon–Ladefoged 2001), emotion and attitude marking (see e.g. Gobl–Ní Chasaide 2003), various kinds of boundary marking (e.g. Dilley et al. 1996; Lennes et al. 2006), conversational (e.g. Redi–Shattuck-Hufnagel 2001), and socio-cultural (e.g. Henton–Bladon 1988). In Hungarian, its boundary marking function has been thoroughly investigated. As shown by Markó's monography (2013), glottal marking appears in utterance-final position, on phrase-initial vowels, and in V(#)V clusters (particularly at word boundaries). Since in the present study we analysed sentence readings, we also focus on the function of boundary marking.

Kohler (2001: 282–285) defined four types of glottalization covering "the glottal stop and any deviation from canonical modal voice" as follows. (1) The first type includes vowel-related glottalization phenomena which signal the boundaries of words or morphemes beginning with vowels. (2) Plosive-related glottalization phenomena belong to another category in his system, these occur as reinforcement or even replacement of plosives. The third group is (3) syllable-related glottalization phenomena which characterize syllable types along a scale from a glottal stop to glottalization (Danish stød among others). He also separated (4) paralinguistic function of glottalization phenomena at the utterance level with two subtypes: (i) phrase-final relaxation of phonation, and (ii) truncation glottalization, i.e. utterance-internal tensing of phonation at utterance breaks. From these four types, two occur frequently in Hungarian speech, (1) vowel-related glottal marking and (4) paralinguistic glottal marking, especially the subtype (i) phrase-final relaxation of phonation (see Markó 2013).

The occurrence of glottal marking was found to show gender-related differences in many languages. A number of studies have found creaky voice to predominate among male speakers, e.g. Stuart-Smith (1999) in Glasgow; Esling (1978) in Edinburgh; Henton and Bladon (1988) for speakers of RP and 'Modified Northern' English.

Nevertheless, despite strong associations between creaky phonation and male gender, the opposite tendency is also documented in the literature. For example, in college-aged women in Virginia (Lefkowitz 2007, cited by Podesva 2013), creaky voice was found to be prevalent, and young Californian women also use it significantly more frequently than their male counterparts (Yuasa 2010). Podesva (2013) found similar tendencies independently of age and race. In Hungarian females' speech, creaky voice was found more frequent than with male speakers of the same age groups (see Markó 2013).

The age-related tendencies of glottal marking have been studied mainly as a function of aging. Some studies did not detect any difference in jitter and shimmer values between young and old adults (e.g. Brown et al. 1989), while others did (e.g. Benjamin 1981; Biever–Bless 1989; Orlikoff 1990; for Hungarian see Bóna 2009). In Hungarian, neither the frequency of occurrence of glottal marking nor the gender and speech style related variation were different between the young and the elderly (Markó 2013).

Only a few studies have been devoted to the analysis of glottal marking in children's speech. In terms of age, the data are far from being consistent, but this is hardly surprising given how many variables might influence the phenomenon. Athanasopoulou et al. (2015) analysed 5-, 7- and 10-year-old children compared to adults. They found that at higher ages,

variation in the pattern of glottal marking resembled adult speech more. Therefore, they hypothesized that this phenomenon was learned from adult speech. Traunmüller and Eriksson (2000) found no glottal marking in 7-year-old children's speech.

As for Hungarian, both the frequency of occurrence of glottal marking and the positional characteristics have been studied mainly in adult speech. Some studies have addressed differences between young adults and elderly (see Bóna 2009; Markó 2013), but the developmental aspect and children's speech have not received the attention it deserves. Tóth (2016) found glottal marking to be present in the speech of 11-year-old Hungarian monolingual children. In her thesis, Tóth (2017) found that neither age nor gender had an effect on the frequency of occurrence of glottal marking between the ages of 7 and 18 years.

Numerous studies found that many aspects of speech of adolescents do not yet show the same patterns that adults' speech does (e.g. realization of phonemic contrasts). Glottal marking is elicitated by physiological reasons on the one hand, and on the other hand its occurrence is learnt to some extent. Therefore the question may rise what differences and similarities appear in the two age groups' speech.

The adolescent subjects in the present study are 16-17 years old. One's voice undergoes mutation during childhood. The age of 16-17 years is approximately the end/last phase of this mutation. Hacki and Heitmüller (1999) summarized the findings on mutation for both boys and girls as follows: Premutation, mutation and postmutation were observed in boys in most studies, while in girls, only Pedersen and his colleagues (1990) found these three phases of mutation. The structure of the vocal chords reaches its final, adult-like structure at the age of 17, and the maturity of the fibers and the structure were found to reflect the phonatory functions (Ishii et al. 2000). The larynx grows to a larger extent in puberty in boys than in girls, sexual dimorphism appears from these changes (e.g. Kahane 1978). The exact timing of the f0 changes is different across studies (see Hacki–Heitmüller 1999). The decrease of habitual, speaking f0 was found at the age of 7-8 years in girls, and at the age of 8-9 years in boys in Hacki's and Heitmüller's results (1999), while Böhme and Stuchlik (1995) found this lowering between 7 and 11 years. Hacki and Heitmüller (1999) found the first signs of mutation at the age of 10-11 years. Böhme and Stuchlik analyzed children up to the age of 14. They could not draw a typical voice profile for the 13-14-year-old boys, thus they linked mutation to this age. Mutation itself takes place at the age of 10-14 years in girls, and at the age of 11-16 years in boys, with postmutation taking place at the age of 16-18 years (Hacki et al. 2013). Mutation does not only mean the decrease of f0 and the broadening of the f0 range. The f0 changes during speech without the subject's intention, and also the posterior portion of the vocal chords may stay open ("mutational triangle") in boys (Hacki et al. 2013). The subjects of the present study are at the latest phase of mutation, in which their organs are almost adult-like, but still in development and their voice is still undergoing changes. Therefore, their speech may not yet pattern entirely like the adults'.

The present study aims to produce data on the distribution and typical position of glottal marking in adolescent speech in comparison to adults in reading aloud of 25 sentences. When it comes to Hungarian adults, it is well-documented that female speakers are much more likely to produce glottal marking (Markó 2013). Even though a fair number of studies exist on the frequency of occurrence of glottal marking in Hungarian adult speech (e.g. Bőhm–Shattuck-Hufnagel 2007, Bőhm–Ujváry 2008, Bőhm 2010, Markó et al. 2019), systematic analysis of the various functions of it (based on the same and well-balanced speech material) is hard to come by (e.g. Markó 2013, 2014).

A meaningful comparison between adult and adolescent data requires the fine-grained analysis of adult speech, which the present study aims to supply. Based on the above considerations, our research questions were formulated as follows:

Q1: How often does glottal marking appear in adolescents' speech compared to adult speakers' speech?
Q2: Do the same phonetic positions trigger glottal marking in adolescents' and adults' speech?
Q3: Does adolescent speech display the same gender-related differences as adult speech (as described by previous studies)?

The corresponding hypotheses were the following:

H1: Glottal marking in general is less frequent in adolescents' speech compared to adults.
H2: The boundary marking function of glottal marking is already observable in adolescent speech; however, the frequency of glottal marking in these positions is lower compared to the corresponding positions in adult speech.
H3: Based on personal experience, gender-related variation was expected in adolescents' speech similarly to adults. In particular, girls and women were supposed to produce more glottal marking than boys and men, however, we expected less frequent glottal marking in the case of girls than in women.

2. Methods

The present comparative study was prompted by the fact that a speech database building project called TiniBEA had been launched at the Research Institute for Linguistics. The speakers of the recordings were 16 to 17-year-old secondary school students. The most important advantage of this corpus is that the same institute had also developed an adult speech database with a very similar recording protocol and under the same laboratory conditions (see Gósy 2012; Gyarmathy and Neuberger 2015). Therefore, the speech samples are easy to compare. In order to balance the samples in terms of gender, we only used the data of 16 teenage speakers, 8 girls and 8 boys (as at the time of the study these samples were available), selecting the same number of male and female speakers from the adult speech database as well. The 16 adult speakers' age varied between 20 and 45 years. The same adult speech material had been analysed in terms of glottal marking in previous studies (e.g. Markó 2013), with the result that in adults, age did not have an effect on the relevant glottal marking characteristics. Therefore, the wide age range of adult speakers was not expected to confound the data. All speakers were native speakers of standard Hungarian, with no speech or hearing deficits. The recordings were carried out in a sound attenuated room with an AT4040 microphone.

For the present study, we selected from the databases the sentence reading task where the speakers were asked to read aloud 25 sentences. The sentences are the same in the two corpora, and their order is also fixed. The sentences are all declarative, but varying in length (15 to 27 syllables). They include simple and complex sentences, and their phonetic structures are also diverse (e.g. 0 to 3 V(#)V sequences appear per sentence). We have to admit that the databases were not specifically designed for the analysis of glottal marking, but all of the sentences offer some opportunity for this kind of investigation. For example, glottal marking typically

occurs at the end of sentences, and most sentences contain word-initial vowels and vowel-clusters both within words and at word boundaries, which all favor glottal marking (Kohler 2001).

Labeling and acoustic analysis were carried out with Praat (Boersma–Weenink 2016). The sound files were labeled manually. The sentences were labeled into sounding and pause intervals. Their durations were calculated based on these labels, with the durations of pauses ignored.

The analysis of glottal marking was performed in accordance with the methodology of previous studies (e.g. Dilley et al. 1996), combining visual and auditory information. Acoustically, glottal marking was identified when (i) the duration or amplitude of the basic periods suddenly changed to a significant extent (including the occurrence of a glottal stop, see Dilley et al. 1996); or when (ii) the fundamental frequency suddenly fell below the speaker's normal pitch range. In addition, as a perceptual criterion, cases in which the timbre was audibly hoarse or creaky were taken into consideration. Following the general practice in the literature on phonation types, no particular quantitative criterion was set up for glottal marking. The parts pronounced with glottal marking were labeled from the start point to the end point (Figure 1) based on visual inspection of the oscillogram and the spectrogram as well as auditory checking.

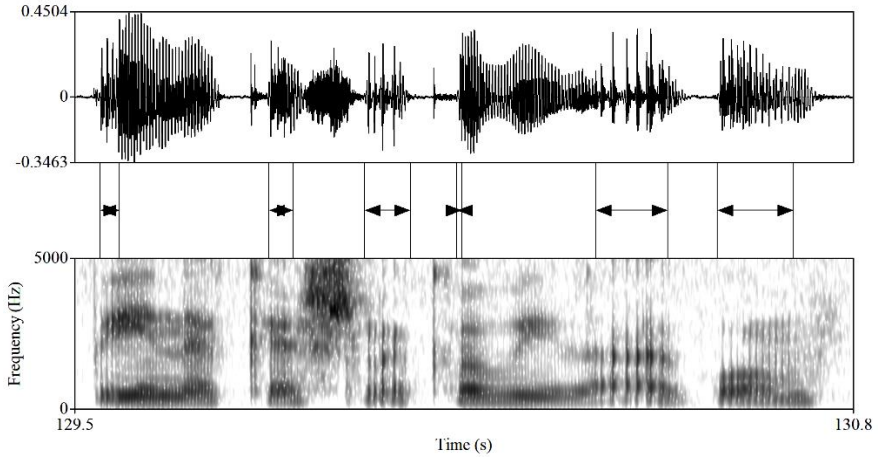

Figure 1. Sample of labeling method.
Arrows show the start and end points of glottally marked parts

Data in terms of gender as well as age were compared based on three parameters of **frequency of occurrence:**

(M1) number of glottally marked speech intervals (any long continuous speech section produced with glottal marking) per utterance (N);
(M2) ratio of duration of glottal marking to the total duration of the utterance (%);
(M3) ratio of the syllables produced (partially or fully) with glottal marking to the total number of syllables per utterance (%).

One might wonder why we applied three different methods to the analysis of frequency of occurrence (from (M1) to (M3)). We decided to combine these methods because the various studies concerning glottal marking generally use one of them (see e.g. Bőhm–Ujváry 2008; Markó 2013), but the same paper has never compared the results obtained by different methods.

In order to see the theoretical problems inherent in each method, we can take extreme scenarios which, however, do occur in speech. With regard to the first method (M1), we may

consider the example of a long pause-to-pause interval with one short part produced with glottal marking (possibly of just a single syllable) as against the entire utterance displaying glottal marking. Both of these realizations give 1/interval as a result. If we measure durations (M2), we obtain two extreme values, one close to 0%, and one at 100%, which is a more plausible description of these two specific occurrences. However, in (M2) an interval produced with glottal marking of the same length can result in different values depending on whether it appears in a short or in a long pause-to-pause interval. Thus this method also hides the real length of glottal marking. If we compare a V(#)V position (which is frequently marked with glottal marking but it is necessarily short due to its function) and a phrase-final position where glottal marking can be of any length, the method has no way of discriminating between these cases. Depending on the carrier pause-to-pause interval they can receive the same duration ratio with (M2). (M3) also considers the length of the phrase (but in syllable number), and thus has the same disadvantages as (M2).

The other problem that may arise is that glottal marking can only appear in voiced sounds. Thus voiceless or devoiced sounds may interrupt an interval produced with glottal marking. This means that while counting the number of intervals with glottal marking, we need to decide whether to count an occurrence of glottal marking extending before and after a voiceless consonant as 1 or 2 intervals. This decision is relevant for (M1) and (M2) as it affects the number of parts produced with glottal marking. Also, when such occurrences are considered as one interval each, the duration of non-voiced parts is added to the duration of glottal marking even though it is not phonated at all.

In order to see how these theoretical problems can be resolved, we compared our data obtained with the three methods. We decided to consider glottally marked stretches of speech extending before and after non-voiced parts as two occurrences of glottal marking. The rationale behind this was that although the physical parameters may not change to favour modal voicing, the causes of glottal marking may be manifold. Thus, for example, a V(#)V glottal marking does not necessarily have an underlying reason for the specific voicing type that would automatically result in its continuation after a non-voiced break. However, considering all types and causes of glottal marking at each occurrence one by one would not be methodologically viable.

The positional analysis determined the ratio of glottally marked vowels to the number of all vowels in the utterance. We analysed the vowels in three positional groups.

Vowel-related glottal marking (see Kohler's (2001) category (1)): vowels located word-initially and/or participating in a vowel cluster either on word boundary or within a word were counted, and this amount was considered 100%. Then we defined the number of vowels in this group which had been pronounced with glottal marking, and determined their ratio.

Sentence-final glottal marking: the vowels of the last three syllables were considered 100%, and we determined the ratio of those vowels in this group which were produced with glottal marking.

Finally, in the miscellaneous group we counted all the other vowels which did not belong to either the vowel-related or the sentence-final group, and defined the ratio of vowels produced with glottal marking.

We compared the frequency and positional data in terms of gender and age group, so here we present the results in four groups: FEMALE ADOLESCENTS, MALE ADOLESCENTS, FEMALE ADULTS and MALE ADULTS.

Linear mixed models were run with age group and gender as factors (Bates et al. 2015). Their interaction was allowed. The speaker was set as a random factor. The number of glottally marked intervals, the ratio of syllables produced with glottal marking, and the ratio of the duration of glottally marked intervals were set as dependent variables in three different models.

The comparison of the syllable types (two triggering glottal marking, and one miscellaneous) was carried out with the means of repeated measures ANOVA. The three syllable types were set as the within-subject effects, the ratio of glottally marked syllables was set as the dependent variable. Statistical analysis was carried in R (R Core Team 2018).

3. Results

3.1. Frequency of occurrence of glottal marking

3.1.1. Number of occurrences (of any length) per utterance. First we analysed the number of glottally marked intervals in the sentences regardless of their length. Figure 2 shows the mean and the standard deviation of the results calculated for the four analysed speaker groups. No difference was found between the adolescent gender groups, while adult men used glottal marking less frequently and adult females more frequently than the adolescent subjects (FEMALE ADOLESCENTS: 4.5±2.4; MALE ADOLESCENTS: 4.4±2.4; FEMALE ADULTS: 5.0±2.7; MALE ADULTS: 4.0±2.1). The individual differences were the lowest in the speech samples of the adult men, all three other groups showed large variability among the speakers. According to the linear mixed model, the differences were not significant between the analysed speaker groups.

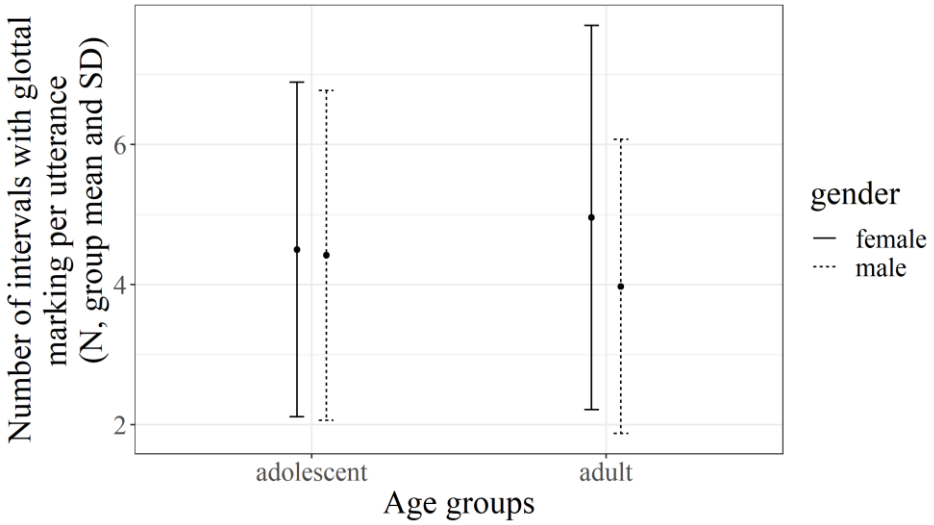

Figure 2. Number of intervals containing glottal marking per utterance (mean and SD)

3.1.2. Ratio of syllables with (any length of) glottal marking to the total number of syllables in the sentence. We also calculated the frequency of occurrence of glottal marking by calculating the ratio of the glottally marked syllables in the utterances. Figure 3 introduces the mean and the standard deviation values for the speaker groups in question (FEMALE ADOLESCENTS: 26.3%±13.6%; MALE ADOLESCENTS: 25.5%±12.9%; FEMALE ADULTS: 29.6%±12.9%; MALE ADULTS: 24.3%±12.7%). While this calculation method may differ from the previous one as one glottally marked interval may include more than one syllables, in the present specific data these two calculations show the same tendencies. This means that there was no difference between adolescent women and men with regard to the ratio of syllables with glottal marking, and the adult women had the highest ratio, adult men the lowest. Though both measurements showed some difference between the adult gender groups, interspeaker variability is large, and therefore no statistical difference could be detected (according to linear mixed models).

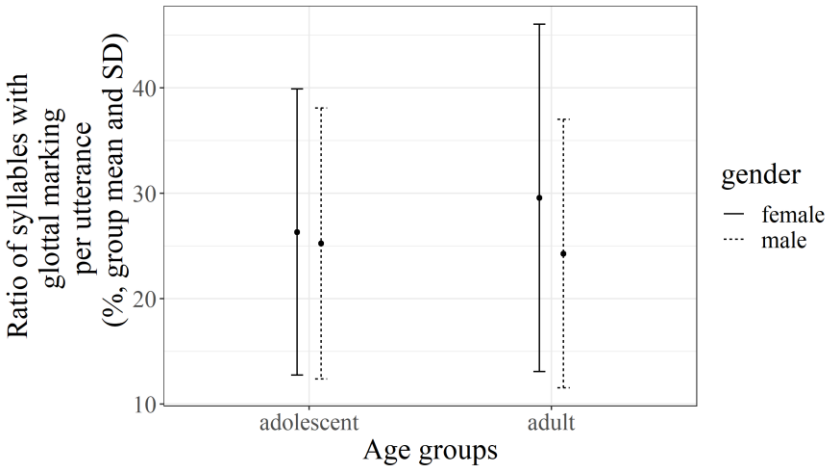

Figure 3. Ratio of syllables produced with glottal marking per utterance (mean and SD)

We analysed what proportion of the syllables of the utterances was pronounced with glottal marking. Roughly one fourth of the syllables displayed this voice quality (mean = 26.4%, minimum = 21.1%, maximum = 34.8%). The ratio of syllables produced with glottal marking did not show any correlation with the total number of syllables in the utterance. We analysed the results for the four speaker groups separately as well, but the average ratio for the groups did not show any correlation with the number of syllables per sentence ($p > 0.05$ in each case).

3.1.3. Ratio of the total duration of intervals produced with glottal marking in the sentences. As the intervals with glottal marking may appear with any length in the voiced intervals of the utterance, the number of occurrences may vary between very short (a single glottal stop) and very long (glottal marking across several sounds) values (see Dilley et al. 1996). Figure 4 shows that in terms of duration, the ratio of intervals with glottal marking was somewhat higher in the adult groups than in the adolescent ones (FEMALE ADOLESCENTS: 13.6%±8.2%, MALE ADOLESCENTS: 12.5%±8.3%, FEMALE ADULTS: 13.8%±8.3%, and MALE ADULTS: 15.7%±10.1%). While adult men had the lowest values with regard to the ratio of glottally marked intervals and syllables per utterance, the duration ratio of these was higher than that of the adolescent gender groups. The statistical analysis showed no significant effect on the data.

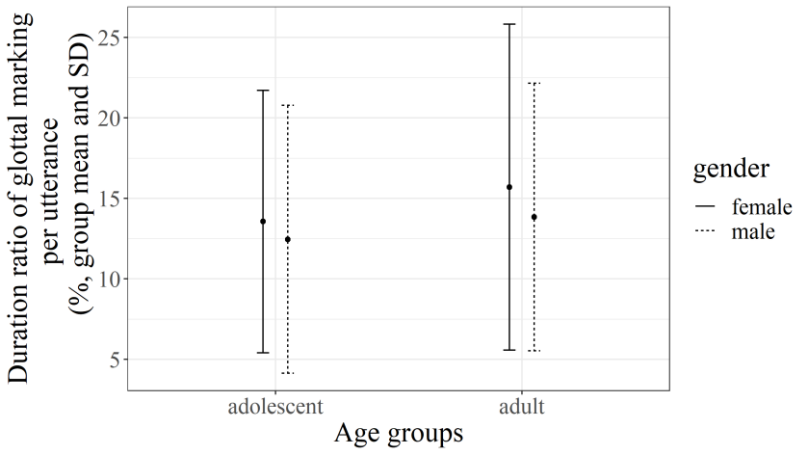

Figure 4. Ratio of the duration of intervals produced with glottal marking per utterance (%)

3.2. The phonetic positions of syllables with glottal marking

The phonetic positions in the sentences that typically trigger glottal marking and those that are not known to do so were also analysed in detail. The first triggering group included two subgroups: vowel-related occurrences, i.e. vowels in vowel boundary positions (word-initial vowels and vowels in V(#)V vowel clusters) and in utterance-final positions, while any other positions belong to the third, so called miscellaneous group.

Approximately half of the vowel-related positions appeared with glottal marking in each speaker group (Figure 5), and again, FEMALE ADULTS showed the highest and MALE ADULTS the lowest ratios.

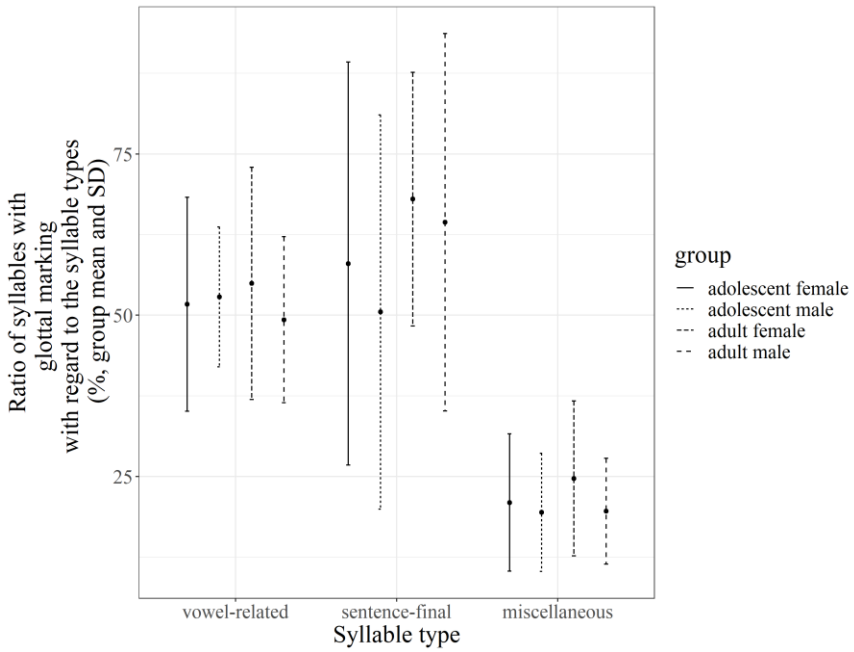

Figure 5. Ratio of vowels produced with glottal marking in vowel-related utterance-final, and miscellaneous positions

Larger differences were detected in utterance-final position. While MALE ADOLESCENT speakers' speech included approximately the same ratio of glottal marking in this position (53.9%±39.1%) as in the vowel-related category, all other participant groups used glottal marking more often in this position (FEMALE ADOLESCENTS: 58.3%±38.6%, FEMALE ADULTS: 68.0%±35.1%, MALE ADULTS: 64.4%±39.2%).

In the miscellaneous positions where glottal marking is not motivated by boundary marking, this type of vocal fold vibration not only occurred much less frequently, but also the standard deviation values, i.e. the differences among the speakers, were lower. The highest ratio of vowels produced with glottal marking appeared in this position again in adult women's reading aloud (25.7%±16.5%) while other speaker groups used this phonation less frequently in this position (FEMALE ADOLESCENTS: 20.9%±13.6%, MALE ADOLESCENTS: 19.4%±13.1%, MALE ADULTS: 19.6%±12.6%). The three positions were also compared to each other. As shown by the results, at least half of the syllables in vowel-related and sentence-final positions were affected by glottal marking in all four groups, with a share of only one fifth or one fourth in the miscellaneous group. The position of the syllable had a significant effect on the ratio of glottal marking (repeated measurements ANOVA: $F(2, 13617) = 66.555$, $p < 0.001$).

3.3. Inter- and intraspeaker variability

Bőhm and Ujváry (2008), and Markó (2013) found that the frequency of occurrence of glottal marking in Hungarian was highly variable among speakers. The variability of the results was also large among our subjects in each age and gender group. Figure 6 shows the interspeaker and intraspeaker variability of the number of glottally marked syllables per second, the mean and standard deviation across the 25 sentences. The number of glottally marked syllables per second in the speech of the subject with the highest mean value is three to four times higher than that in the speech of the subject with the lowest mean value in each group. The criterion of intraspeaker variability showed up more limited differences across speakers, each subject was found to have high variability across the sentences.

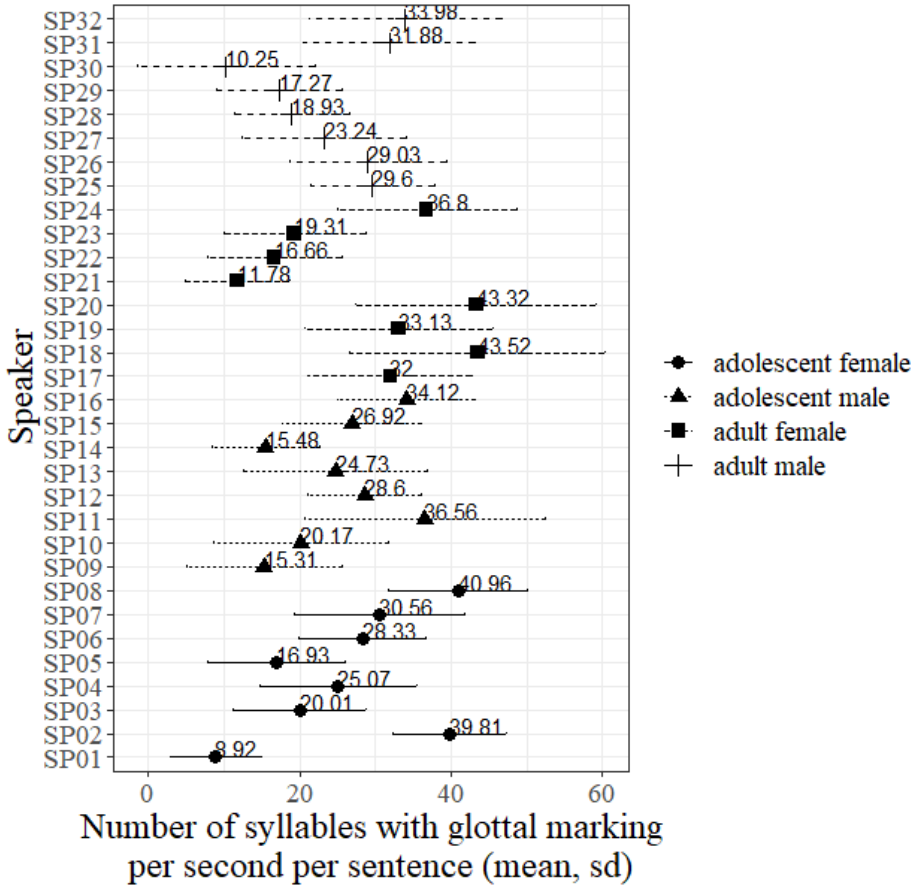

Figure 6. Inter- and intraspeaker variability in the number of syllables with glottal marking

4. Discussion and conclusion

The present study aimed to set a start for the analysis of glottal marking relative to the age of the speaker. We analysed adolescent (16-17 years of age) and adult speakers' sentence reading and compared the frequency of occurrence, ratio of duration and functional/positional dispersion of glottal marking based on the results of previous studies on Hungarian (for a summary, see Markó 2013 and Section 1 of the present paper).

Our data showed similar tendencies in adult age groups as previous studies, i.e. female speakers produced glottal marking more frequently and in a higher ratio of sentence duration

than their male counterparts, however, the present results did not show a statistically significant effect of gender in this age group. Gender-specific differences did not appear in the adolescent age group either.

The positional analysis also confirmed the earlier results, i.e. vowel-related and sentence-final positions triggered glottal marking in a higher ratio than other positions. In the former two, approximately half or more of the syllables, while in the latter one only one fifth or fourth of them occurred with glottal marking.

The three analysed positions showed the same tendencies in the four groups. In the two positions triggering glottal marking, such syllables had a higher share than in miscellaneous positions, for which no regular link with glottal marking had been found in previous studies. This result is important as it shows that the patterns detected by the previous studies for adults are present in the speech of adolescent speakers as well, and neither shows gender-specific differences.

With regard to our hypotheses, certain conclusions can be drawn. Our first hypothesis, namely that glottal marking in general is less frequent in adolescents' speech compared to adults, has not been corroborated. This phenomenon's frequency of occurrence appeared to be rather similar between the age groups. However, adult female speakers tended to apply glottal marking more frequently than adult male or adolescent subjects.

Under the second hypothesis, we expected that the boundary marking function of glottal marking would already be observable in adolescent speech, but the frequency of glottal marking in these positions would be lower than in adult speech. The results confirmed that the same phonetic positions trigger glottal marking in adolescent speech as with adults regardless of which type of triggering position is analysed.

The third hypothesis about gender differences in adolescent speech was not supported by the evidence. Based on our personal experience, we expected that girls produce more glottal marking than boys, similarly to women (compared to men), however, we expected less frequent glottal marking in the case of girls than in women. Although women produced more glottal marking than men, no significant difference was found between women and girls.

We can conclude that the gender-specific differences that appear in adults do not occur in the speech of adolescents. Thus, it emerges later, maybe during early adulthood. The positional patterns are, however, clearly apparent. This means, in particular, that the sentence-final and vowel-related positions with their boundary marking functions and the physiological bases of the sentence-final position prevail over any age- or gender-related differences.

Acknowledgements

The research was founded by the National Research, Innovation and Development Office of Hungary, project No. FK-128814 and the Thematic Excellence Program of ELTE Eötvös Loránd University, Budapest, Hungary. The authors are grateful to Karolina Takács for her valuable help in annotation.

References

Athanasopoulou, Angeliki – Pincus, Nadya – Vogel, Irene 2015. Acquisition of creaky voice in English. Presentation: *LSA Special Session: Aspects of Creaky Voice*, Portland, OR.

Bates, Douglas – Mächler, Martin – Bolker, Ben – Walker, Steve 2015. Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software* 67: 1–48.

Benjamin, Barbaranne J. 1981. Frequency variability in the aged voice. *The Journal of Gerontology* 36: 722–726.

Biever, Dawn M. – Bless, Diane M. 1989. Vibratory characteristics of the vocal folds in young adult and geriatric women. *Journal of Voice* 3: 120–131.

Boersma, Paul – Weenink, David 2016. *Praat: Doing phonetics by computer [Computer program]*. Version 6.0.17. http://www.praat.org/

Bóna, Judit 2009. Az idős életkor tükröződése a magánhangzók ejtésében [Aging shown in vowel production]. *Beszédkutatás* 2009: 76–87.

Bőhm, Tamás 2010. Irreguláris zöngeképzés, glottalizáció, rekedtség [Irregular voice, glottalization, hoarshness]. In: Németh, Géza – Olaszy, Gábor (eds.): *A magyar beszéd. Beszédkutatás, beszédtechnológia, beszédinformációs rendszerek.* Budapest: Akadémiai Kiadó. 167–170.

Bőhm, Tamás – Ujváry, István 2008. Az irreguláris fonáció mint egyéni hangjellemző a magyar beszédben [Irregular phonation as individual voice feature in Hungarian speech]. *Beszédkutatás* 2008: 108–120.

Bőhm, Tamás – Shattuck-Hufnagel, Stephanie 2007. Utterance-final glottalization as a cue for familiar speaker recognition In: *Interspeech 2007. August 27–31, 2007, Antwerp, Belgium.* 2657–2660.

Böhme, Gerhard – Stuchlik, Gisella 1995. Voice profiles and standard voice profile of untrained children. *Journal of Voice* 9: 304–307.

Brown, W. S. – Morris, Richard J. – Michel, John F. 1989. Vocal jitter in young adult and aged female voices. *Journal of Voice* 3: 113–119.

Dilley, Laura – Shattuck-Hufnagel, Stefanie – Ostendorf, Mari 1996. Glottalization of word-initial vowels as a function of prosodic structure. *Journal of Phonetics* 24: 423–444.

Esling, John 1978. The identification of features of voice quality in social groups. *Journal of the International Phonetic Association* 8: 18–23.

Gobl, Christer – Ní Chasaide, Ailbhe 2003. The role of voice quality in communicating emotion, mood and attitude. *Speech Communication* 40: 189–212.

Gósy, Mária 2012. BEA: A multifunctional Hungarian spoken language database. *The Phonetician* 105–106: 51–62.

Gordon, Matthew – Ladefoged, Peter 2001. Phonation types: A cross-linguistic overview. *Journal of Phonetics* 29: 383–406.

Gyarmathy, Dorottya – Neuberger, Tilda 2015. Egy hiánypótló adatbázis: TiniBEA [TiniBEA, a database that fills a gap]. *Beszédkutatás* 2015: 209–222.

Hacki, T. – Heitmüller, S. 1999. Development of the child's voice: Premutation, mutation. *International Journal of Pediatric Otorhinolaryngology* 49(1): 141–144.

Hacki, Tamás – Hirschberg, Jenő – Mészáros, Krisztina 2013.A hangképzés gyermekkori fejlődése, premutáció, mutáció [Development of phonation during childhood, premutation, mutation]. In: Hirschberg, Jenő – Hacki, Tamás – Mészáros, Krisztina (eds.): *Foniátria és társtudományok* [Phoniatrics and associated disciplines]. Vol. 1. Budapest: ELTE Eötvös Kiadó. 213–215.

Henton, Caroline – Bladon, Anthony 1988. Creak as a sociophonetic marker. In: Hyman, Larry – Li, Charles N. (eds.): *Language, speech, and mind.* London: Routledge. 3–29.

Ishii, Kosuke – Yamashita, Kotaro – Akita, Masumi – Hirose, Hajime 2000. Age-related development of the arrangement of connective tissue fibers in the lamina propria of the human vocal fold. *Annals of Otology, Rhinology & Laryngology* 109(11): 1055–1064.

Kahane, Joel C. 1978. A morphological study of the human prepubertal and pubertal larynx. *American Journal of Anatomy* 151: 11–22.

Kohler, Klaus J. 2001. Plosive-related glottalization phenomena in read and spontaneous speech. A stød in German? In: Grønnum, Nina – Rischel, Jørgen (eds.): *To Honour Eli Fischer-Jørgensen.* Kopenhagen: Reitzel. 174–211.

Lefkowitz, D. 2007. Creaky voice: Constructions of gender and authority in American English conversation. *Paper presented at 106th American Anthropological Association.* Washington, DC.

Lennes, Mietta – Aho, Eija – Toivola, Minnaleena – Wahlberg, Leena 2006. On the use of the glottal stop in Finnish conversational speech. In: Aulanko, Reijo – Wahlberg, Leena – Vainio, Martti (eds.): *The Phonetics Symposium 2006.* 93–102.

Markó, Alexandra 2013. *Az irreguláris zönge funkciói a magyar beszédben* [Functions of irregular phonation in Hungarian]. Budapest: ELTE Eötvös Kiadó. http://mek.oszk.hu/15000/15081/15081.pdf

Markó, Alexandra 2014. Az irreguláris zöngeminőség gyakorisága és pozíciói különféle spontán beszédhelyzetekben [Frequency and positions of irregular voice quality in various spontaneous speech situations]. *Beszédkutatás* 22: 69–86.

Markó, Alexandra – Gráczi, Tekla Etelka – Deme, Andrea – Bartók, Márton – Csapó, Tamás Gábor 2019. Megnyilatkozáskezdő magánhangzók glottális jelöltsége a szintaktikai pozíció és a magánhangzó-minőség függvényében [Glottal marking of utterance initial vowels with regard to the syntactic position and vowel quality]. *Beszédkutatás* 27: 30–53.

Orlikoff, Robert F. 1990. The relationship of age and cardiovascular health to certain acoustic characteristics of male voices. *Journal of Speech and Hearing Research* 33: 450–457.

Pedersen, Mette Fog – Moller, S. – Krabbe, Søren – Bennett, Paul – Svenstrup, Birgit 1990. Fundamental voice frequency in female puberty measured with electroglottography during continuous speech as secondary sex characteristic. *International Journal of Pediatric Otorhinolaryngology* 20: 17–24.

Podesva, Robert J. 2013. Gender and the social meaning of non-modal phonation types. In: Cathcart, Chundra – Chen, I-Hsuan – Finley, Greg – Kang, Shinae – Sandy, Clare S. – Stickles, Elise (eds.): *Proceedings of the 37th Annual Meeting of the Berkeley Linguistics Society.* Berkeley: Berkeley Linguistics Society. 427–448.

R Core Team 2018. *R: A language and environment of statistical computing.* R Foundation for Computing, Vienna.

Redi, Laura – Shattuck-Hufnagel, Stefanie 2001. Variation in the realization of glottalization in normal speakers. *Journal of Phonetics* 29: 407–429.

Stuart-Smith, Jane 1999. Voice quality in Glaswegian. *Proceedings of the International Congress of Phonetic Sciences* 14: 2553–2556.

Surana, Kushan – Slifka, Janet 2006. Is irregular phonation a reliable cue towards the segmentation of continuous speech in American English? *Proceedings of Speech Prosody 2006.* Dresden, Germany. http://20.210-193-52.unknown.qala.com.sg/archive/sp2006/papers/sp06_177.pdf.

Tóth, Andrea 2016. Kérdő funkciójú megnyilatkozások kisiskolások beszédében [Utterances with interrogative function in Hungarian young school children's speech]. *Beszédkutatás* 2016. 43–58.

Tóth, Andrea 2017. *A spontán beszéd a nem és az életkor függvényében gyermek- és fiatal felnőttkorban* [Spontaneous speech as a function of gender and age in childhood and young adulthood]. PhD thesis. Budapest: Eötvös Loránd University.

Traunmüller, Hartmut – Eriksson, Anders 2000. Acoustic effects of variation in vocal effort by men, women, and children. *Journal of the Acoustical Society of America* 107: 3438–3451.

Yuasa, Ikuko Patricia 2010. Creaky voice: A new feminine voice quality for young urban-oriented upwardly mobile American women? *American Speech* 85(3): 315–337.