LISTENERS' EVALUATION OF VOICE QUALITY IN HUNGARIAN SPEAKERS

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Introduction

Voice quality is a term used to refer to the "permanently present, background, person-identifying feature of speech" (Crystal 2008: 516). In a narrower sense, phonatory setting is sometimes distinguished from global articulatory setting (from which the global voice quality derives), and voice quality is defined as the result of the (habitual) setting of the larynx. These types of phonation result in such voice qualities as whispery or creaky phonation (Crystal 2008: 37). From another point of view, voice quality is considered the fourth dimension of prosody besides f_0, amplitude and local speaking rate (Campbell–Mokhtari 2003).

In the present paper, we use the term *voice quality* in the sense of 'result of phonation', where the different phonation types result in different voice qualities. The most common type of phonation is modal voice, which is defined in the literature as quasi-periodic vibration of the vocal folds (e.g., Gósy 2004). However, in some cases, voice production may depart from this, and phonation may become non-modal, for instance irregular. Irregular phonation (glottalization) is a phonation type characterized by the irregular vibration of the vocal folds, which usually results in extremely low f_0 values. Although irregularity can show up in a number of forms (see e.g., Batliner et al. 1993; Dilley et al. 1996), it is clearly audible to people with normal hearing. Based on its perceptual characteristics, it is often called creaky voice. (Several other phonation types can be differentiated, e.g., whispery, harsh, breathy; but in the present paper we focus on creaky voice only.)

Creaky voice is more likely to occur toward the end of the intonation phrase (see e.g., Henton–Bladon 1988; Markó 2013), which can be explained by the fact that fundamental frequency gradually diminishes over the course of an utterance. Studies have shown that the frequency of occurrence of creaky voice is highly speaker dependent, and huge differences can be observed in different people's vocal habits (Henton–Bladon 1988; Dilley et al. 1996; Bőhm–Ujváry 2008). It has also been shown that the less speakers glottalize, the more probable it is that they do so at a boundary position (Markó 2013).

Recent years have seen a rise in the number of sociophonetic studies on voice quality (Podesva 2013). There is growing evidence to suggest that,

DOI: 10.15775/Beszkut.2017.55-66

among other effects, phonetic varieties are responsible for triggering listeners' evaluations and beliefs about speakers. These beliefs can pertain to various attributes, from the speaker's age and body size to their cognitive skills, trustworthiness or sex appeal (see e.g., Gósy 2001; Gocsál–Huszár 2003; Anderson et al. 2014; Warner 2015).

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 often than their male counterparts (Yuasa 2010). Podesva (2013) found similar tendencies independently of age and race. In Hungarian young and middle-aged females' speech, creaky voice was found more frequent than with male speakers of the same age groups (although among the elderly, no difference was detected; see Markó 2013).

In conclusion, the interrelations between gender and voice quality are less than straightforward. This may support the hypothesis that phonation types including creaky voice have a more complex (social) "meaning". Several scholars have examined this question, and made a variety of proposals. Brown and Levinson (1987) note that creaky voice can express commiseration or complaint. Others claim that it can support an authoritative stance (Dilley et al. 1996; Lefkowitz 2007, cited by Podesva 2013). Creak is also interpreted as a signal of toughness (Mendoza-Denton 2011). Based on an analysis of job interviews, Anderson and co-authors (2014) conclude that creakiness marks a less competent, less educated, less trustworthy person. Finally, Yuasa (2010) suggests that creak can be a feature of urban-oriented and upwardly mobile, professional young women. In her opinion, women use creaky voice frequently in order to show "the image of educated urban professional women capable of competing with their male counterparts". According to this interpretation, some of the social meanings of creaky voice are rooted in its resemblance to men's voice.

The creaky voice pattern arising in various speaker groups is often explained by iconic associations between creaky voice and masculinity. As creaky voice is accompanied by low pitch, and low pitch is characteristic of male speakers' voice, creaky voice is typically associated with masculinity (Podesva 2013).

This phenomenon probably originates from the frequency code (in the sense of Ohala 1994), which refers to interrelations between the size of the larynx, the vocal folds and the resonating cavities on the one hand, and the frequency features of the acoustic output on the other. If the vocal folds are

shorter, the f_0 and therefore the pitch are higher and vice versa; if the vocal tract is smaller, the formant frequencies are higher and vice versa. In short, this means that smaller body size results in a higher frequency tone, and larger body size in a lower tone. In terms of gender, the differences of speech frequency features stem from the different body sizes of male and female speakers in general. Therefore, creaky voice with its extraordinarily low tone is also associated with attributes which are conventionally associated with men, such as toughness. Similar ideological processes link falsetto, and its characteristically high pitch, to femininity (see Podesva 2013).

However, several results appear to contradict these simple patterns. For instance, in a study, the voice of a (Hungarian) male person was shifted to both higher and lower f_0s, and these samples were played to more than 900 participants. Respondents rated the lower pitched voice as more feminine (Rácz–Papp 2015). Podesva (2013) therefore suggests that "the social meanings of particular phonation types are culturally specific and should not be reduced to purely iconic or unanalysed associations to either gender or race" (428).

Although the number of sociophonetic studies on voice quality has increased recently, the phenomenon cannot be analysed independently of vocal behaviour in all its complexity. We cannot verify the effect of creakiness in everyday situations since our impressions derive from the total picture. Having said this, several methods are already available for modifying voice quality in a controlled manner (e.g., speech synthesis extended with regular-to-irregular voice transformation, Csapó–Németh 2014). In the present research, we used one of these methods, and created minimal pairs of modal vs. creaky realizations of the same utterances. The manipulation process affected only voice quality, leaving fundamental frequency and speech rate unmodified. Our research questions were the following:

Does voice quality (modal vs. creaky) have an effect on listeners' evaluation of the speaker's personality? If it does, which attributes are considered to be affected by creaky voice? Do these differences depend on the gender of the speaker or the general "voiceprint" of the speaker?

Based on previous studies, we assumed (H1) that differences in voice quality (modal vs. creaky voice) would result in different evaluations given by the respondents. We also hypothesized (H2) that the gender of the speaker would have a significant effect on the results. Finally, the evaluations were expected to be highly speaker-dependent (H3).

Subjects, method, material

For the present study, sentence readings of 3 male and 4 female speakers were selected from the BEA Hungarian speech database (Gósy 2012). Four declarative sentences were used, all of which belonged to the formal register (the numbers stand for the Utterance ID):

(02) *Az ügyfeleknek kompromisszumot kellett kötniük.* 'The clients had to make a compromise.'

(08) *Hétvégén a gyerekek a Bakonyba mennek kirándulni.* 'At the weekend the children are going on an excursion to the Bakony mountain.'

(13) *A kalauz szigorúan ellenőrzi a menetjegyeket és az igazolványokat.* 'The ticket inspector is closely checking the tickets and the cards.'

(23) *A hegyimentőknek sűrű ködděl kellett megküzdeniük.* 'The mountain relief crew had to struggle with dense fog.'

Each sentence was modified between the modal vs. irregular poles with an automatic modal-to-irregular transformation tool (Csapó–Németh 2014). The transformation was based on speech analysis-synthesis, and manipulated the excitation signal. The input was a speech waveform with 16 kHz sampling rate and 16 bit linear quantization. First, residual analysis was performed. The fundamental frequency (f_0) parameter was calculated by a continuous pitch tracker (Garner et al. 2013) with 25 ms frame size and 5 ms frame shift. In the next step cepstral analysis was performed on the speech signal using the SPTK toolkit. The residual signal (excitation) was obtained by inverse filtering. Next, the SEDREAMS Glottal Closure Instant detection algorithm (Drugman et al. 2012) was used to find the glottal period boundaries in the voiced parts of the residual signal. Subsequently, the windowed pitch periods of the residual were multiplied by a random gain in the range of [0, 2.0] and they were overlap-added. This random scaling of the pitch cycles ensured that the transformed excitation would be irregular. Finally, spectral filtering was applied to retrieve the transformed speech signal from the residual. During the transformation, selected short regions of the speech samples were manipulated with the regular-to-irregular transformation algorithm, with the rest of the utterances left unchanged.

Previous studies have shown that in both read and spontaneous speech, it is typically the final part of the utterances that becomes irregular (e.g., Bőhm–Ujváry 2008; Markó 2013). Hence, we decided to convert the final four syllables of each utterance to irregular.

The modified speech samples were prepared by the second author, and then the first and third authors evaluated these samples and agreed that the modified samples sounded 'normal'.

We conducted a subjective listening test in order to measure the effects of creakiness in voice. Participants were recruited via Facebook and mailing lists. No incentives were offered. First, participants had to fill in a background questionnaire on personal details such as their age, gender, and profession. Speech experts' responses were excluded from the data analysis.

27 people participated, all of whom were native speakers of Hungarian, 20 females and 7 males between the ages of 21 and 55 years (mean of 32 years).

The original and modified samples were played in random order to the participants, who were asked to evaluate the samples for specific attributes (see

below) in an online questionnaire. Respondents completed the experiment in their own web browsers.

The participants listened to each speech sample twice. In each turn, five attribute scales were supplied for rating the person whose voice they had just heard. A total of ten 5-point attribute scales (each a Likert-scale of 1-5) were used:

1) dumb – smart,
2) aggressive – placid,
3) introverted – extroverted,
4) fake – natural,
5) sober – passionate,
6) sloppy – elegant,
7) unreliable – trustworthy,
8) unfriendly – friendly,
9) non-feminine – feminine,
10) non-masculine – masculine;

where the attributes on the left were marked with 1 and those on the right were marked with 5 in each case. Both presentations of the same speech sample were to be assessed on either the non-feminine – feminine or the non-masculine – masculine attribute scales. Additionally, four more scales were selected at random from the remaining eight attribute scales. Within a turn, the order of attribute scales was also randomized.

The data were analysed with the General Linear Mixed Model. The target variable was the result of the Evaluation, while Voice quality (modal vs. creaky), the Utterance, the Speaker, the Gender of the speaker and the Gender of the respondent as well as the Attribute were introduced as fixed effects (interactions between the factors were not analysed). The evaluations of each pair of original and modified samples were compared using paired sample *t*-test.

Results

The results of the statistical analysis were the following: we found significant effects only in the case of Utterance [$F(12, 7466) = 3.329$, $p < 0.001$], Speaker [$F(20, 7466) = 25.139$, $p < 0.001$], and Attribute [$F(36, 7466) = 49.268$, $p < 0.001$], while Voice quality, Gender of the speaker, and Gender of the respondent did not show any significant effect on the results.

Since the total picture showed that listener evaluations had been influenced by the Speaker and the Utterance, we carried out a pairwise comparison for each Speaker and Utterance combination in order to analyse the effect of creakiness on the evaluations for each attribute scale. We assumed that the patterns arising in special cases would allow us to spot tendencies even if the GLMM did not detect significant differences.

In the following tables (Table 1 to Table 7), the significant (or close to significant, indicated by grey background) differences are presented as a function of attribute scales. In the "Modal voice evaluation" and "Irregular voice evaluation" rows, the averages of the given Likert-scale points are presented for the modal and the glottalized samples, respectively. The average values are based on 27 participants' evaluations in each case.

Table 1 summarizes the data of utterance pairs showing significant pairwise differences on the dumb – smart attribute scale. With two female and one male speakers, a significant difference was detected between the modal and modified (irregular) utterances; however, the tendencies are not uniform. With respect to speakers 003 and 166, creaky voice was evaluated higher on the dumb – smart attribute scale. By contrast, speaker 064 was considered less smart based on the irregular sample.

Table 1: Significant results of pairwise comparisons on the dumb – smart attribute scale

Gender of the speaker	Female	Male	Female
Speaker ID	003	166	064
Utterance ID	23	23	08
Modal voice evaluation	2.5	2.8	3.5
Irregular voice evaluation	2.8	3.1	3.0
Level of significance (*p*)	0.036	0.057	0.021

On the aggressive – placid attribute scale, two (one male and one female) speakers' original and modified samples differ significantly (Table 2). The two display opposite tendencies, though, with speaker 085's irregular sample evaluated as more aggressive than her modal one, while the reverse is true for speaker 026.

Table 2: Significant results of pairwise comparisons on the aggressive – placid attribute scale

Gender of the speaker	Female	Male
Speaker ID	085	026
Utterance ID	13	13
Modal voice evaluation	4.3	4.0
Irregular voice evaluation	3.9	4.3
Level of significance (*p*)	0.009	0.005

Two female speakers' modal and irregular samples differ significantly in terms of naturalness (Table 3). In both cases, respondents judged the irregular utterances to be less natural.

On the sober – passionate attribute scales, one male and one female speaker's utterances show up significant differences (Table 4). With regard to the male speaker, the creaky sample was evaluated as less passionate, while the opposite tendency was observed for the female speaker.

Table 3: Significant results of pairwise comparisons on the fake – natural attribute scale

Gender of the speaker	Female	Female
Speaker ID	085	003
Utterance ID	02	08
Modal voice evaluation	3.4	2.7
Irregular voice evaluation	2.8	2.2
Level of significance (*p*)	0.002	0.025

Table 4: Significant results of pairwise comparisons on the sober – passionate attribute scale

Gender of the speaker	Male	Female
Speaker ID	166	085
Utterance ID	13	13
Modal voice evaluation	2.1	2.0
Irregular voice evaluation	1.8	2.3
Level of significance (*p*)	0.026	0.043

With respect to the sloppy – elegant, unreliable – trustworthy and non-feminine – feminine attribute scales, only one significant result was obtained for each. Therefore, the data are presented in one table (Table 5).

Table 5: Significant results of pairwise comparisons on the sloppy – elegant, unreliable – trustworthy and non-feminine – feminine attribute scales

	Sloppy – elegant	**Unreliable – trustworthy**	**Non-feminine – feminine**
Gender of the speaker	Male	Male	Male
Speaker ID	166	166	166
Utterance ID	23	08	23
Modal voice evaluation	2.6	3.0	1.8
Irregular voice evaluation	2.9	3.6	1.9
Level of significance (*p*)	0.011	0.023	0.043

All of the differences concern the modal and irregular versions of the same speaker's two utterances. The creaky samples were evaluated as more elegant, more trustworthy and more feminine. (The non-masculine – masculine

scale was analysed independently of the non-feminine – feminine scale, but no significant difference was found in the case of the previous one, this is why it is not indicated in any of the tables.)

On the unfriendly – friendly and introverted – extroverted attribute scales, two women's samples produced significant differences (Table 6). In particular, creaky voice was considered friendlier and more extroverted.

Table 6: Significant results of pairwise comparisons on the unfriendly – friendly and introverted – extroverted attribute scales

	Unfriendly – friendly	**Introverted – extroverted**
Gender of the speaker	Female	Female
Speaker ID	085	064
Utterance ID	02	02
Modal voice evaluation	3.3	2.7
Irregular voice evaluation	3.8	3.1
Level of significance (*p*)	0.037	0.022

General tendencies cannot be observed, the differences are rather sporadic. From a global perspective, however, the data still indicate a pattern of differences between male and female speakers' samples. The evaluation of voice qualities appears to be sensitive to the gender of the speaker. Firstly, this is reflected in the fact that on several attribute scales, we found significant differences either only for men or only for women, namely along the fake – natural, sloppy – elegant, unreliable – trustworthy, non-feminine – feminine, unfriendly – friendly and introverted – extroverted scales. Secondly, on the dumb – smart, aggressive – placid and sober – passionate attribute scales, creaky voice affected listeners' judgments differently with regard to male and female speakers. Based on creaky voice samples, female speakers were judged both more and less smart, less aggressive, less natural, more passionate, friendlier and more extroverted than based on modal counterparts. Male speakers were evaluated smarter, less aggressive and passionate, more elegant, more trustworthy and more feminine based on the irregular voice samples compared to the modal ones.

Since the pairwise analysis resulted in significance on several attribute scales in the case of two speakers, we collected their data in Table 7. The interpretation of creakiness is less than fully consistent, especially with the female speaker (085), where the same utterance was judged both less natural and friendlier, while the same speakers' various utterances were judged friendlier and more aggressive.

Table 7: Significant results of the pairwise comparisons in case of speaker 085 and 166

Gender	Speaker ID	Utterance ID	Modal voice	Creaky voice	Sign. (*p*)	Interpretation: *creaky is*
Female	085	02	3.4	2.8	0.002	*less natural*
			3.3	3.8	0.037	*more friendly*
		13	4.3	3.9	0.009	*more aggressive*
			2.0	2.3	0.043	*more passionate*
Male	166	23	2.8	3.1	0.057	*more smart*
			2.6	2.9	0.011	*more elegant*
			1.8	1.9	0.043	*more feminine*

Discussion

In the present study, we analysed the effect of creakiness on the evaluation of speakers. For the first time in this field of study, we used an automatic modal-to-irregular transformation tool (Csapó–Németh 2014) to modify the voice quality of utterances. The only difference between the stimuli was in voice quality (modal vs. irregular); all other parameters (e.g., articulation rate, stress, f_0 in other parts of the utterance) were left unchanged. Due to the automatic tool, the effect of the human speaker's variance of speech was eliminated between the paired (modal vs. irregular) utterances. However, as the results have shown, this artificial modification did not influence the speaker-dependency of evaluations. In accordance with the previous literature, we modified the final part of the utterances (the last four syllables). The pre-test evaluation of the samples guaranteed that the stimuli were human-like, and the creaky parts sounded "normal".

Generally, GLMM results showed that Speaker, Utterance and Attribute had an effect on listeners' evaluation, while the speaker's (or the respondent's) Gender or Voice quality did not. On the other hand, no straightforward interrelation was detected between creakiness and gender or attribute.

Based on the earlier literature, we assumed (H1) that differences in voice quality (modal vs. creaky voice) would result in different evaluations given by the listeners. This effect was not confirmed in general, but in some cases of speakers and utterances it was verified by paired *t*-test. While some differences measured up to the level of significance, it was still not clear if they were necessarily relevant. In order to find an answer to this question, we decided to subject the stimuli to further tests (see below).

We also expected (H2) that the gender of the speaker would have a significant effect on the results. GLMM did not prove this effect, either; however, gender-dependent patterns were detected on several attribute scales. Finally,

we expected (H3) that the evaluations should be highly speaker-dependent, which was confirmed by GLMM.

It is clear from the results that the tendencies are rather divergent and contradictory to some extent. Creaky voice modified the results in opposite ways along the dumb – clever, aggressive – placid and sober – passionate attribute scales. In two cases, the creaky realizations were evaluated as less natural, and the creaky versions of utterances were considered more extroverted, more elegant, more trustworthy, more friendly and more feminine – each in one case.

Because of the diversity of the data, we performed a short control subjective listening test in order to measure the noticeability of the voice quality differences. We used those samples as stimuli which showed any significant difference in the modal vs. irregular pairwise comparison in the earlier study (5 speakers, 8 utterances). In this second experiment, ten pairs of utterances were played in random order to the listeners, who heard both the modal and the creaky versions of the same utterance within a turn, but the order of these two versions was random. This time six attributes were analysed: smartness, aggressiveness, naturalness, trustworthiness, friendliness and masculinity. Respondents evaluated the samples in the following way. While they were listening to the samples, three statements (with respect to one attribute) were displayed for each pair of stimuli, for instance: *the speaker of the first utterance is smarter – they are equal – the speaker of the second utterance is smarter*. Respondents were asked to choose one statement by clicking on it. The questionnaire was accessed through the Internet, and respondents completed the experiment in their own web browsers. They had been recruited through Facebook and mailing lists. 14 respondents participated in this follow-up experiment (none of them had participated in the previous one): 12 females, 2 males, aged between 22 and 27 years (average of 23 years).

According to the results, listeners were not able to detect the difference in voice quality, 72% of the answers was “equal”. Most of the respondents who commented on the experiment remarked that they had been unable to detect any difference between the members of the utterance pairs. The remaining 28% of the responses also appears to be random, with no evidence of clear tendencies.

The question therefore arises as to why the irregularity is unnoticeable. One likely reason is the ratio of creakiness within the utterance. We used modal-to-irregular manipulation on only the final 4 syllables, since the end of the utterance is the typical place of irregularity. But this could also mean that listeners are not so sensitive to creakiness in the utterance final position, having been accustomed to it. Therefore, we have plans to extend the modal-to-irregular manipulation to a larger part of the utterances.

Speaker dependency can be considered as another reason: perhaps the interrelations between voice quality and other acoustic parameters such as

fundamental frequency or articulation rate also have an effect. Therefore, we are planning to add further acoustic characteristics to the model.

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A beszélő hallgatói megítélése a zöngeminőség alapján

A jelen kutatás az irreguláris zöngeminőség (glottalizáció) hatását vizsgálta a beszélő hallgatói megítélésére. Annak érdekében, hogy csupán a zöngeminőség különbségét tesztelhessük, mondatfelolvasásból származó, modális zöngével ejtett megnyilatkozásokat módosítottunk beszédtechnológiai eszközökkel úgy, hogy a megnyilatkozás utolsó 4 szótagjában irregulárissá változtattuk a zöngeminőséget. Ezeket a megnyilatkozásokat (az eredeti és a módosított változatokat) véletlenszerű sorrendben 27 adatközlő hallgatta meg, és a beszélő személyiségvonásait (pl. buta-okos, megbízható-megbízhatatlan) ötfokozatú skálán értékelték. A „zöngeminőség" modális vagy irreguláris volta önmagában nem eredményezett szignifikáns eltérést az eredményekben egyik tulajdonság tekintetében sem, és a „nem"-nek sem igazolódott a hatása. Szignifikáns tényezőnek mutatkozott ugyanakkor a „beszélő", a „személyiségvonás" és a „megnyilatkozás".