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Factors associated with vocal fry among college students

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Abstract

Purpose: Vocal fry is increasingly used in everyday speech. The purpose of this study was to identify associated factors of vocal fry among young US college-age students.

Method: Forty college students participated in a cross-sectional study. Participants produced speech under nine different room acoustic conditions (simulated). The recorded speech was perceptually evaluated by three speech-language pathologists. Multivariate logistic regression analysis was used to identify variables (individual, environmental) associated with the perceptual assessment of vocal fry.

Result: A high occurrence of perceptually identified vocal fry was identified among college students. Two factors were significantly associated with lower occurrence of perceptually identified vocal fry: one individual (sporadic consumption of caffeinated beverages) and one environmental factor (speaking in an environment with background noise).

Conclusion: Similar to modal phonation, fry-like phonation seems to be influenced by individual and environmental factors. Therefore, clinicians interested in including this technique as part of their intervention programs may take into account the caffeine consumption and the background noise conditions of the room where the therapy will take place in order to facilitate the production of fry-like phonation.

Keywords

vocal fry; perceptual voice assessment; associated factors

INTRODUCTION

Vocal fry has been related to communicative purpose and vocal health issues. While *persistent* use of vocal fry may be linked with a reduction in the voice quality (1–4), *sporadic* vocal fry might indicate a physiological normal larynx being used for linguistic, pragmatic and metalinguistic functions (5–8). Furthermore, in clinical settings, fry phonation is used as a technique in during the treatment of some voice problems (9). Therefore, the existence of vocal fry may be not abnormal and may be just another phonational register (5, 10).

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Previous research has focused on characterizing the physiological, perceptual, acoustic and communicative characteristics of vocal fry in order to identify differences from modal voice or from other voice symptoms, such as hoarseness or roughness (11). Compared to modal phonation, vocal fry is produced with a lower cricothyroid and interarytenoid muscle activity, and an increased thyroarytenoid activity (12). Vocal fry production have been also described as an irregular vocal fold vibration characterized by a short open phase and a long closed phase (5). Fry phonation should be distinguished from “glottalized voice” that is defined as “a voice that contains frequent transient sounds that result from relatively forceful adduction or abduction during phonation” (13). Perceptually, vocal fry is characterized as a creaky sound with a rough vocal quality (5). From the acoustical perspective, fundamental frequency of vocal fry pulses has been reported to be between 18 Hz and 65 Hz (far below compared with modal voice) (10, 12, 14), with no significant differences between males and females (10). From the communicative perspective, vocal fry seems to serve as a syntactic marker because of its increased occurrence at the end of paragraphs or sentences (6, 15, 16).

Some studies have investigated the association between individual characteristics, such as gender and language, with the occurrence of vocal fry. Concerning the relationship between gender and vocal fry, the results are contradictory with some authors reporting that males use vocal fry more frequently than females (17) and others presenting opposite results (15). In regards to the relation between language and vocal fry, Redi et al (2001) suggests the presence of other intermediate factors, such as dialect and locations in the utterance. Nevertheless, there appears to be a lack of studies in the relationship between vocal fry with individual factors (such as allergies, alcohol consumption, smoking, caffeine consumption) and environmental factors previously reported to be associated with voice quality and voice disorders (e.g. room acoustics, background noise).

Due to the use of vocal fry in the voice clinic as well as its increasingly common use in everyday speech, there is a need for studies to investigate the effect of individual and environmental factors (previously reported to be associated with voice quality) in the production of this vocal register. This information may be of interest for clinicians during the design of treatment programs that involve vocal fry to improve different voice production’s mechanisms. Additionally, this information may be of interest to linguist and other communication specialist when studying intelligibility, phonemic changes, and turn taking.

In order to address these gaps of knowledge, the current cross-sectional study of 40 US college students was designed with two aims: (1) determine the occurrence of perceptually identified vocal fry, and (2) identify individual and environmental factors associated with vocal fry.

METHODS

Design and Participants

This study was performed during the spring of 2016. After approval of the Michigan State University Human Research Protection Program, undergraduate college students were invited to participate in this cross-sectional study, thereby creating a study population large

enough to meet the required sample size with sufficient discriminatory power. To this end, 40 college students (22 females and 18 males) between the ages 20 and 25 years old (mean= 22; SE= 0.2) were recruited for the study. Participants were monolingual native speakers of American English predominantly from the Midwestern United States (Michigan= 33 participants; Illinois= 1 participant; Ohio= 2 participants; California= 2 participants; Georgia= 1 participant; Texas= 1 participant). After giving written informed consent to participate in this study, participants filled out a four-part questionnaire (e.g., demographic and voice-related questions) and recorded one speech sample (Rainbow passage) under nine different “virtual-simulated” acoustic conditions.

Data collection procedures

Questionnaire—The questionnaire presented to the participants consisted of four sections. The first section of the questionnaire included nine questions on socio-demographics (e.g. age, gender and education), native language, and history of hearing or speech disorders. The second section contained 21 multiple-choice questions on the occurrence, severity and frequency of voice symptoms during the last year, the last month, and the day of the experiment, as well as a self-report of vocal fry. The third section included eight multiple-option questions on health-related conditions that have been previously reported as associated factors of voice complaints; e.g. respiratory diseases, gastritis, gastroesophageal reflux (18–20). The last section contained six multiple-choice questions on lifestyle habits known to be associated with voice complaints (e.g. alcohol consumption, caffeinated beverages’ consumption, and smoking) (21–23).

Voice samples—Participants were asked to read out loud the first six sentences of “The Rainbow Passage” (24), equal to about 30 seconds of speaking, under nine different “virtual-simulated” acoustic conditions. These nine acoustic conditions were made up of all combinations of three different virtual acoustic environments (reverberation times) and three background noise conditions. The mid-frequency reverberation times were 0.4 s (Low), 0.8 s (Medium) and 1.2 s (High). The three background noise conditions were: (1) without artificial noise; (2) with artificial classroom babble noise at about 61 dBA at 1m from the subject; and (3) with artificial pink noise at about 61 dBA at 1m from the subject. The order of administration of the nine scenarios was randomized to provide an equal distribution of any (short-term) vocal fatigue across all the tasks, as well as to control for any unknown confounding variables relating to task order.

Equipment—Speech samples were recorded by an omnidirectional microphone (M2211, NTi Audio, Tigards, OR, USA) placed at a fixed distance of 30 cm from the mouth of the participant. The microphone output was split in two signals: the first for direct recording and the second for creating the virtual acoustic environment. The direct digital recording (44,100 Hz) was accomplished using an external sound board (UH-7000 TASCAM, Teac Corporation, Montebello, CA, USA) connected to a personal computer (PC) running Audacity 2.0.6 (SourceForge, La Jolla, CA). For the virtual environment, the direct microphone output was combined with one of three noise types (played from the PC) using a digital mixer (MultiMix 8 USB FX 8, Alesis, Cumberland, RI, USA). The mixed signal of the participant’s voice and noise was digitally processed to add reverberation using a real-

time effect processor (MX400, Lexicon, South Jordan, UT, USA) and played back to the participant using headphones (SRH840, Shure, Niles, IL, USA). Figure 1 illustrates the measurements.

Perceptual assessment by speech-language pathologist—The presence/absence of vocal fry in speech was quantified by listening to the last sentence of the Rainbow passage first paragraph: “When a man looks for something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow.” The last sentence was chosen because it has been suggested that the likelihood of vocal fry increases at the end of paragraphs. Specifically, it has suggested this increased likelihood is caused by the voiced sound that is usually present in the final word in a sentence, a characteristic that seems to increase the tendency to drop pitch and loudness (6, 7).

Audio files of the last sentence were randomly presented to the three listeners, all speech-language pathologists (9 acoustic scenarios $\times$ 40 subjects = 360 files). For each sentence sample, the listeners indicated if they perceived vocal fry in the speech production and, if so, how “persistent” it was. Perceptually, vocal fry has been described as a “popping of corn” or a “creaky voice”, so the instructions for the perceptual identification of vocal fry used the occurrence of a “popping corn” sound. The persistence of vocal fry was evaluated on a 4-point rating scale (0 for no vocal fry, 1 for short presence of vocal fry, 2 for moderate duration/presence of vocal fry, and 3 for persistent presence of vocal fry). For most of the samples, the “persistence” of vocal fry rating was not above one; therefore, a dichotomous variable was used in the statistical analysis with subjects having a score for persistence/severity of vocal fry of one or above considered to be affected individuals.

Reliability of perceptual assessments—In an attempt to maximize intra- and inter-listener reliability for the perceptual assessment, one speech-language pathologist (SLP) coordinated with the other two on how to rate and what to listen for. A measure of intra-reliability for each listener and inter-reliability among the listeners was calculated using a Kappa statistic. For the intra-reliability assessment, 30% of the voice recordings (large enough to allow for reasonable estimates of reliability) were randomly selected to be rated a second time by each SLP. Therefore, each listener listened to a total of 468 samples.

Statistical Analysis

All statistical analyses were performed by means of SPSS 21 (IBM Corporation) in three steps. First, differences in occurrence of perceptually identified vocal fry under the nine different acoustic conditions were assessed by Cochran’s Q test. Second, the unweighted Cohen’s Kappa coefficient was used to assess intra- and inter-listener agreement of the perceptual assessment of vocal fry. Third, Generalized Estimating Equations (GEEs) were used to determine which individual characteristics and room acoustic parameters were associated with the presence of perceptually determined vocal fry. For the independent variables, those with a p-value of maximal 0.20 in the univariate analyses were included in the multivariate analysis in order to avoid residual confounding (25), and were only retained when the p-value reached the conventional level of significance of 0.05. The magnitude of

the association was expressed by the odds ratio (OR), and the statistical significance as the 95% confidence interval (95% CI).

RESULTS

Participant characteristics

Table 1 shows that around 38% reported drinking at least one cup or glass of “caffeinated beverages, which include coffee, tea, or caffeinated soda pop” per day, while around 78% of the participants reported to drink at least one glass of alcoholic beverages (beer, liquor or wine) per week. Concerning the health-related conditions, 70% reported having experienced symptoms of a cold during the previous month. In regards to the self-reported voice symptoms, 45% reported having had voice symptoms in the last year.

Occurrence of perceptually identified vocal fry

Figure 2 shows the perceptually identified prevalence (in percentage) of vocal fry among the 40 participants under the nine different “simulated” room acoustic conditions: three reverberation times (Low, Mid, High) and three noise conditions (Normal, Pink, Babble). No significant differences in the proportion of perceptually identified vocal fry (prevalence) were identified among the nine different acoustic conditions (*Cochran’s Q test*= 7.66; *p-value* 0.47). Our results in the reliability assessment indicated a good intra-listener agreement of the principal researcher (kappa coefficient=0.71). In contrast, a fair inter-listener agreement between the three SLPs was found (kappa coefficient=0.33).

Associations with perceptual assessment of vocal fry

Table 2 shows those factors that were statistically associated with the occurrence of perceptually identified vocal fry during the production of the last sentence of the Rainbow passage. Female gender (OR=2.0) was associated with an increased occurrence. In contrast, age (OR=0.8) self-reported sporadic consumption of caffeine (OR=0.4), babble background noise (OR=0.8) and pink background noise (OR=0.7) were associated with a lowered likelihood. The multivariate analysis showed that, after adjustments for those variables statistically significant in the univariate analysis, only sporadic consumption of caffeinated beverages (OR=0.3), babble background noise (OR=0.5) and pink background noise (OR=0.4) remained associated with perceptually identified vocal fry.

DISCUSSION

The aim of this study was to address the influence of individual and environmental factors on the occurrence of perceptually identified vocal fry. Confirming previous research, our findings also suggest that babble background noise and pink background noise reduced the likelihood of vocal fry perceptually identified by SLP. Not examined in previous studies was the association between sporadic consumption of caffeinated beverages and a lower likelihood of perceived vocal fry. Our results in the univariate analysis suggested an increased chance of producing vocal fry among females (OR=2.0), and a decreased likelihood of producing vocal fry among younger college students (OR=0.8), but after adjustments for those variables statistically significant in the univariate analysis, these associations did not remain.

Our findings on the relationship between age and vocal fry are in line with the results of Oliveira et al (2016), who found no significant difference in the occurrence of vocal fry by age among 40 US women. Table 2 shows that in the univariate analysis there is a tendency of reduction of vocal fry when age increases. However, this association between age and perceptually identified vocal fry does not remain after adjustments. Moreover, the inclusion of the variable age in the multivariate analysis does not change the significant univariate associations. Therefore, although age is not a statistical associated variable in our study (probably due to the short range of age of our participants), it was included in the multivariate model to explore how the occurrence of vocal fry may (or not) varies among our participants due to this individual factor. As to the gender effect in the occurrence of vocal fry, the literature is mixed and our results indicate no effect. We suggest two reasons why some have reported a higher occurrence of vocal fry among females compared with males (6, 15). First, Abdelli-Beruh et al (2014) reported the occurrence of vocal fry over three sentences of the Rainbow passage, whereas we used only the last sentence for the analysis of vocal fry's occurrence. Since it has been reported an increased likelihood of vocal fry at phrase boundaries, it is possible that both males and females present similar vocal behavior at the end of the sentence but different behaviors earlier in a spoken passage. Second, Redi et al (2001) found a significant difference by gender among professional speakers, but the occurrence of vocal fry among nonprofessional speakers was not significantly different. The students participating in this study were nonprofessional speakers, so it would be expected that males and females would have a similar occurrence of vocal fry.

Our results suggested no significant differences in the proportion of subjects perceptually identified with vocal fry (prevalence) through nine different "virtual simulated" acoustic conditions, which may indicate no relationship between room acoustics (RT + BNL) and prevalence of perceptually identified vocal fry at group level. However, there appeared to be an association between background noise conditions and the perceptual identification of vocal fry, suggesting the influence of noise conditions on the perceptual identification of vocal fry at individual level. Specifically, our results indicated that US college students are less likely to fry under noisy conditions. These findings are in agreement with previous research that reported a decrease in the degree of vocal fry as an effect of noise (26). Likely this can be traced to talkers' tendency to increase their voice levels in noisy conditions as a result of their auditory feedback (Lombard reflex) (27), which is produced through increased vocal effort accomplished by increased laryngeal engagement and lung pressure (breath support). However, because the vocal folds become thicker during vocal fry due to an unopposed thyroarytenoid muscle contraction, generating higher resistance to the respiratory driving force and lower airflow rates (12, 28), a loud vocal fry would require an increased tension when attempting to increase the loudness (p. 79) (2). This type of vocal production is difficult, which means the production of vocal fry under noisy conditions is less likely.

A new finding in this study was the relationship between self-reported caffeinated beverages' consumption and perceptually identified vocal fry. Our results suggest that those students who reported sporadic consumption of caffeinated beverages (5 or less cups per week) had significantly lower odds of being perceptually identified with vocal fry compared to students who reported no consumption of caffeinated beverages. Consumption of caffeinated beverages has been identified as a risk factor for voice problems because of

caffeine's drying effect on laryngeal tissue (29). Previous studies have reported that during vocal fry, the vocal folds mucosa present more vibration amplitude due to the shortening in medial position of the vocal folds (30). Assuming the consumption of caffeinated beverages has a drying effect on laryngeal tissue, the mucosal tissue stiffness would increase, which would raise the phonation threshold pressure, thereby needing more effort (lung pressure) to initiate voicing and decreasing the ease of fry production. Therefore, presence or absence of vocal fry within a designed vocal task may indicating slight changes to vocal fold mucosa and have some diagnostic value similar to attempts at other such vocal tasks (31, 32).

Concerning the self-reported dosage of caffeine consumption, we propose two possible reasons to explain why sporadic rather than frequently consumption of caffeinated beverages was significantly associated with perceptually identified vocal fry. Firstly, previous research have concluded that consumption of 250 mg of caffeine (2–3 cups of coffee) may be associated with irregularity of fundamental frequency, and therefore vocal quality (33). This dosage of caffeine consumption is similar to the one reported in our study (less than 5 cups). In addition, it has also been suggested that frequent consumption of caffeine might produce tolerance (34). Therefore, it may be hypothesized that, among our participants, moderate consumption of caffeinate beverages may generate the drying effect needed to increase the mucosal tissue stiffness in the right proportion to make more difficult fry production. However, the increasing on the consumption of caffeinated beverages may have a different effect. Nevertheless, since in our study, the information on caffeinated beverages consumption was based on self-reports, and we did not perform laryngeal examination, future research is needed to identify the proportion of consumption of caffeinated beverages needed to produce changes on voice production. Secondly, due the cross-sectional nature of this study, we can talk about relation rather than causation of caffeinated beverages in vocal fry. Low fry production and sporadic consumption of caffeinated beverages may be considered healthier lifestyle habits compared with high fry production and frequently consumption of caffeinated beverages. Therefore, our results on a positive relationship between these two factors may indicate a higher awareness of healthy lifestyle habits among those participants. Future research is needed to investigate further the influence of lifestyle habits in the occurrence of vocal fry and, therefore, their contribution to vocal health.

Because previous studies has reported the efficiency of the therapeutic use of vocal fry for improving glottic insufficiency and velopharyngeal sphincter closure, the production of vocal fry has been introduced in voice therapies' plans (30, 35). Knowledge of the two mentioned associated factors of vocal fry is of relevance for the plan of voice therapies where vocal fry is used to improve different voice production's mechanisms (36). The results of the present study on the association between sporadic caffeinated beverages' consumption and background noise conditions with the occurrence of vocal fry is of interest to clinicians who may take into account the noise conditions of the room and the consumption of caffeinated beverages during patient intake (history) and voice therapy planning. Thus, if the aim of the therapy is increasing the production of vocal fry, the clinician might develop therapy sessions in rooms with low background noise and may also suggest avoiding caffeinated beverages. In contrast, if the objective of the therapy is to avoid vocal fry (e.g., patients changing Male-to-Female Transsexual Voice (37) or with vocal fatigue (7)), the clinician might conduct sessions in rooms with babble or pink background

noise. Finally, because the sporadic consumption of caffeinated beverages had an effect on vocal fry, people whose voice quality is an important component of their lifestyle may need to consider the effect of these beverages.

As in all research, there are several limitations. The first limitation relates to the cross-sectional design, which does not allow to examine the relationship over time between perceptually identified vocal fry and individual factors and room acoustics. Second, although our results on the intra- and inter-reliability suggested good intra-listener agreement, we found fair agreement between listeners, which is in line with a previous study that reported a mean value for inter-judge reliability of 0.47 for vocal fry (26). Previous studies have reported different sources of low inter-listener agreement in perceptual assessment (38, 39). In the current study, the perceptual assessments by the three listeners were performed in different places under different conditions. Other internal factors, such as listener fatigue or perceptual sensitivity of the listener have been reported. However, we do not have enough information to speculate on the influences of these internal factors in the perceptual assessments performed by the three listeners. Third, the small sample size of our study does not allow generalization of the reported associations. Further studies on larger sized samples would be advisable to corroborate the obtained results.

CONCLUSION

In conclusion, similar to modal phonation, fry-like phonation seems to be influenced by individual and environmental factors. Therefore, clinicians interested in including this technique as part of their intervention programs may take particular note of the caffeine consumption and the background noise conditions of the room where the therapy will take place which will influence the production of fry-like phonation. Likewise, these factors could influence the study of fry usage in normal speech communication by linguists.

Future research could go beyond the perceptual identification of vocal fry to a more quantitative/automated method. To do this, the acoustical characteristics of fry need to be identified. Recent work in this direction is the power peak detection (PwP), interpulse similarity measure (IPS), and automatic detection methods as reliable measures of vocal fry (40, 41). The PwP detects the power changes in individual glottal pulses of vocal fry segments by means of the highlight of amplitude variation within individual pulses. The IPS is defined as the maximum cross-correlation value between the current power peak and the ones around the previously detected power peaks, which allows discriminating between vocal fry pulses and unvoiced regions. This and other acoustical characterizations of fry may be feasible methods for objective assessment of vocal fry segments in continuous speech samples (41). Such advances may allow for the distinction between the common fry in normal communication and that found in disordered voices. Additionally, assuming that the frequent and long-term use of fry has vocal health consequences, only through quantitative identification could the vocal risk be quantified over time.

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Figure 1.
Recording setup illustrating the signal path for recording and for creating the virtual environment.

Figure 2.
Prevalence (in percentage) and its Standard Error of perceptually identified vocal fry under nine different acoustic conditions.

Table 1.

Socio-demographic characteristics, health-related conditions and voice symptoms of 40 college students

Variable	Female (n=22)		Male (n=18)	
	N	%	N	%
<i>Lifestyle habits</i>				
Smoking (yes)	0	0	1	6
Alcohol consumption (yes)	17	77	14	78
No consumption of coffee (0/week)	7	32	8	44
Sporadic consumption of coffee (5/week)	10	45	5	28
Frequently consumption of coffee (6/week)	5	23	5	28
<i>Health-related conditions</i>				
Cold (yes)	18	82	10	56
Laryngitis (yes)	4	18	1	6
Respiratory (yes)	11	50	10	56
Sinus (yes)	11	50	3	17
Gastritis (yes)	3	14	6	33
Gastroesophageal Reflux (yes)	9	41	10	56
Self-reported hearing impairment (yes)	1	5	2	11
<i>Voice symptoms and vocal fry</i>				
Voice symptoms last year (yes)	13	59	5	28
Voice symptoms last month (yes)	6	27	4	22
Voice symptoms today (yes)	3	14	2	11
Self-reported Vocal fry (yes)	4	18	1	6

Table 2.
Associated factors of vocal fry during production of the last sentence of “Rainbow passage.”

Variable	Univariate analysis		Multivariate analysis Individual Factors		Multivariate analysis Environmental Factors		Multivariate analysis Full model	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Socio-demographics								
Age	0.8+	(0.6 – 1.1)	0.8	(0.6 – 1.2)			0.9	(0.6 – 1.4)
Female	2.0+	(0.9 – 4.6)	2.1	(0.8 – 5.5)			2.1	(0.8 – 5.4)
Lifestyle habits								
Alcohol consumption	0.9	(0.4 – 0.9)						
Caffeinated beverages consumption								
No consumption of caffeinated beverages	1.0	Referent	1.0	Referent			1.0	Referent
Sporadic consumption of caffeinated beverages (5/week)	0.4*	(0.1 – 1.0)	0.3*	(0.1 – 0.7)			0.3*	(0.1 – 0.9)
Frequently consumption of caffeinated beverages (> 6/week)	1.2	(0.4 – 3.4)	0.8	(0.3 – 2.7)			1.3	(0.4 – 4.1)
Health-related conditions								
Cold	1.4	(0.5 – 3.7)						
Laryngitis	0.5	(0.2 – 1.9)						
Respiratory	0.8	(0.3 – 1.8)						
Sinus	1.4	(0.6 – 3.4)						
Gastritis	1.4	(0.5 – 4.1)						
Gastroesophageal Reflux	1.5	(0.7 – 3.5)						
Self-reported hearing impairment	0.7	(0.2 – 2.5)						
Reverberation Time								
Low RT (0.4 s)	1.0	Referent			1.0	Referent		
Medium RT (0.8 s)	1.1	(0.8 – 1.6)			1.1	(0.7 – 1.6)		
High RT (1.2 s)	1.0	(0.8 – 1.3)			1.0	(0.8 – 1.3)		
Background Noise								
No Noise	1.0	Referent			1.0	Referent		
Babble Noise	0.8+	(0.5 – 1.1)			0.7+	(0.5 – 1.1)	0.5*	(0.4 – 0.8)

Variable	Univariate analysis		Multivariate analysis Individual Factors		Multivariate analysis Environmental Factors		Multivariate analysis Full model	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
	0.7+	(0.4 – 1.1)			0.7+	(0.4 – 1.1)	0.4*	(0.2 – 0.8)

* p<0.05

+ p<0.20, considered for inclusion in the multivariate logistic regression analysis