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Categorization of Vocal Fry in Running Speech

Katherine Proctor
kproct@bgsu.edu

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CATEGORIZATION OF VOCAL FRY IN RUNNING SPEECH

CATEGORIZATION OF VOCAL FRY IN RUNNING SPEECH

KATHERINE PROCTOR

HONORS PROJECT

Submitted to the Honors College
at Bowling Green State University in partial fulfillment of the
requirements for graduation with

UNIVERSITY HONORS 12/9/19

Dr. Ronald Scherer, Communication Sciences and Disorders,
College of Health and Human Services, Advisor

Dr. Katherine Meizel, Musicology/Ethnomusicology,
College of Musical Arts, Advisor

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INTRODUCTION

The concept of a vocal register has been defined by Hollien (1974) as “a series or range of consecutive frequencies that can be produced with nearly identical voice quality.” There are three different vocal registers in speech production according to Hollien (1974). These registers are: loft, which is the highest of the three, and could be described perceptually as the “falsetto” range; modal, which is the middle range and is evident in “normal” speech production; and pulse, the lowest range of phonation that is characterized by popping, pulsing sounds. These three registers can be differentiated based on perceptual, acoustic, physiologic, and aerodynamic factors. This honors project will primarily focus on pulse register, which is commonly known as *vocal fry*.

Vocal fry has been perceptually described, according to Blomgren et al. (1998), as having a similar sound to that of “popping corn”. Others have likened it to the sound of “bacon frying”. This is due to the relatively long phonatory cycle with a short glottal open phase and the creation of acoustic excitations, such that individual vibrations, or pulses, are perceived (Blomgren, Chen, Manwa, & Gilbert, 1998). The long phonatory cycle creates the relatively low pitch of this register. Vocal fry has also been perceived as a characteristically softer register, particularly compared to modal, or normal, speech (Hollien, 1974).

Studies have shown clear acoustic differences between vocal fry register and modal register. As for modal register, the fundamental frequency (F_0) has been measured at 100-240 Hz, depending on the sex of the speaker, with females tending to have a higher F_0 for this register. Vocal fry, however, has an average F_0 that ranges from 20-70 Hz (Blomgren, Chen, Manwa, & Gilbert, 1998). This average differs from even the lowest F_0 values of the modal register range, which Murry and Brown (1971) found to be approximately 73-98 Hz.

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Additionally, Hollien (1974) noted that vocal fry seemed to be nearly acoustically identical for males and females (with males being 7-78 Hz and females being 2-78 Hz).

Vocal fry is associated with a set of specific physiological correlates. The vocal folds separate and then come back together rapidly at the beginning of a phonatory cycle, after which they stay together for a relatively long period of time during the same cycle. The vocal ligament becomes less stiff and the vocal folds thicken, which directly affects the speed of the vocal folds and ultimately creates an abnormal vibratory cycle (Cielo, Elias, Brum, & Ferreira, 2011). Some authors have suggested that over the vocal fry cycle there may only be one open-close-closed pulse, while others have said up to three may occur. Scherer (1989, 1990, 2017) documents a variety of vocal fry patterns, including single pulse fry, double pulse fry, and multiple pulse fry.

There is a characteristic reduction of airflow that co-occurs with the production of vocal fry as opposed to modal register. According to Murry and Brown (1971), the airflow of modal register is approximately 70-180 mL/s, while the airflow of vocal fry is closer to 10-100 mL/s. According to Hollien (1974), the subglottic pressure of vocal fry register was “slightly higher” than that of modal register. McGlone and Shipp (1971), however, noted that the differences in subglottic pressure were not very significant (their research showed that air pressure ranged from 2.5 to 7.6 cm H₂O for vocal fry, and from 2.8 to 7.0 cm H₂O for modal). Thus, it is clear that different research suggests that subglottal pressure is not inordinately high during vocal fry production. It is important to note, however, that airflow consistently is shown to be the lowest during vocal fry compared to the other vocal registers, due to the long glottal closed time during each cycle.

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Vocal fry is a phenomenon that is prevalent in a number of social and cultural aspects. Abdelli-Beruh et al. (2012) demonstrated that the use of vocal fry is evident in most female college students who use Standard American English. According to Anderson et al. (2014), there are conflicting views on how vocal fry affects the perception of American women. While some argue that it may make these women appear more educated, and thus favorable, others argue that the “fashion trend” of vocal fry has more negative perceptions, particularly among older generations. An experiment conducted by Anderson et al. (2014), however, confirmed the latter: that the use of vocal fry by young women led to people perceiving these women as “less competent, less educated, less trustworthy, less attractive, and less hireable.” Furthermore, this study showed that vocal fry use in females was perceived more negatively than in males. Another study, conducted by Hull et al. (in press), noted that even communication disorders graduates perceived vocal fry as “undesirable,” associating these voices with qualities such as disinterest, vanity, and lack of engagement. Borrie et al. (2017) demonstrated an interesting phenomenon of “conversational entrainment” of vocal fry. For this study, two young adult female conversational partners, one that used vocal fry and one that did not, spoke with twenty other young adult females. The females who spoke to the conversational partner using vocal fry tended to use more vocal fry themselves, whereas the females who spoke to the conversational partner not using vocal fry used substantially less vocal fry in their conversation. This could help to explain the high frequency of vocal fry usage in young American speakers when engaged in conversation. Vocal fry is also evident in non-conversational studies. According to a study by Gibson (2017), young adult women use vocal fry even in the production of nonwords (particularly in unstressed syllables). It is clear that the frequent use of vocal fry, particularly among young American women, may have negative cultural and social impacts.

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There are various clinical aspects of vocal fry. Abdelli-Beruh et al. (2012) have suggested that the selective use of vocal fry in social situations is not necessarily harmful, but that the habitual use of vocal fry could lead to vocal pathologies. Abdelli-Beruh et al. (2012) note that this is the case for several reasons. Vocal fry is naturally softer than modal speech, so in order to get the same loudness effect, vocal fry is often produced with increased tension in the vocal mechanism, and this prolonged tension is not necessarily healthy. Also, vocal fry tends to correlate with vocal fatigue, although Abdelli-Beruh et al. (2012) note that future research is necessary to fully understand this relation. It is also important to differentiate between a client's use of vocal fry for social reasons, and a client exhibiting vocal fry as a side effect of some pathological issue. For instance, according to Blum (2016), respiratory and neurological issues, muscle tension dysphonia, and lesions on the vocal folds can all cause an individual to use vocal fry in speech. Recognizing that vocal fry can be part of the cause, and be caused by, specific vocal pathologies emphasizes the importance of studies surrounding vocal fry usage.

The ultimate *purpose of this project* is to develop a categorization system to label different patterns of vocal fry in a specific, descriptive, and accurate way. Once this is accomplished, the frequency of occurrence of these categories will be determined, and syllables will be examined in voice samples to determine where the different types of fry tend to occur within syllables. Such a categorization system has not been reported in the scientific literature. Such a system, however, may be most appropriately applied to the clinical situation of vocal diagnostics and vocal therapy approaches.

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METHODS

The data used in this study were obtained from a dissertation by Perrine (2018) on the effects of stress on the voice. Of the 19 healthy female participants aged 18-23 in Dr. Perrine's study, 5 of those participants had their voice recordings analyzed for the purpose of this study. These participants included the unidentified subjects F19, F17, F15, F11 and F9.

In the study by Perrine (2018), the participants read the Rainbow Passage several times. For the purpose of this project, the 2nd voice recording of each of the five participants was analyzed because this was a basal voice recording prior to the participants being subjected to the experimental stressor (creating and giving a short speech).

A computer program called Praat was used to analyze the microphone signals and other spectrographic features of the voice recordings of The Rainbow Passage. Dr. Perrine and Dr. Scherer had previously marked occurrences of vocal fry in each syllable in the voice samples with the use of a text grid to add these labels and other important information. In order to do this, visual and auditory cues were used to identify the vocal fry. The syllables containing vocal fry were sectioned off by blue dividers in the text grid and labeled. For the purpose of this study, the incidences of vocal fry in the recordings of the five participants were re-examined at length, and new decisions were made during this refinement phase of fry detection.

Dr. Scherer and Dr. Perrine discussed several different types of vocal fry in the dissertation, including prototypical fry, aperiodic fry, period double fry, and onset fry, and some of these were labeled in the text grids for the voice recordings. For this study, the goal was to re-examine these existing categories, and develop new ones, as well as refine the definition of vocal fry.

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It was determined that the syllables containing vocal fry would be divided into four relatively even sections: the onset, earlier, later, and final portions of the syllables. The syllables were divided this way due to the fact that, early on, we noticed that several different types of vocal fry could occur throughout one syllable, and therefore dividing it up this way made it easier to organize these data.

It was also decided, upon reviewing the voice samples carefully, that there are specific criteria for the existence of vocal fry. The criteria are as follows:

1. Vocal fry is produced when an acoustic transient is created near the moment of glottal closure, followed by a relatively long closed time before the next cycle starts, seen acoustically (in the microphone signal).
2. Vocal fry is not a low frequency modulation of a normal speaking fundamental frequency (such a modulation may belong to the category “creaky voice”).
3. Vocal fry can occur approximately an octave below the fundamental frequency of normal speech for a particular speaker. E.g., a female speaker may produce vocal fry at a frequency of 100 Hz if the frequency of her modal speech was approximately 200 Hz.
4. Vocal fry appears primarily to be a physiological phenomenon created by glottal adductory gestures (not directly studied in this research project, but being pursued in a separate Honors College project with Kiersten McCormick and Dr. Scherer).

During this process, six categories of vocal fry were developed, as well as subcategories. Once these categories were developed, the type of fry relative to the four positions in the syllable was determined and recorded within the embedded text grid for each of the voice samples. The examples of fry were then re-examined in order to verify the classifications, and necessary changes were made. For this document, examples were chosen and will be presented. The count

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of each category relative to the subjects will be presented in a table in order to show the frequency of occurrence of each category.

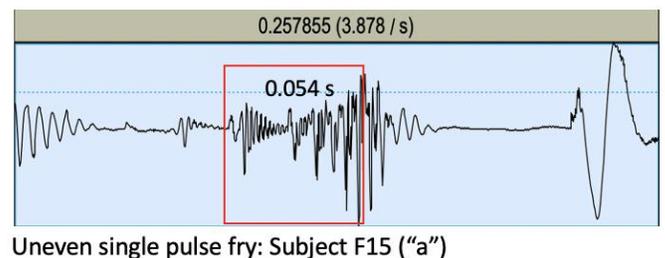
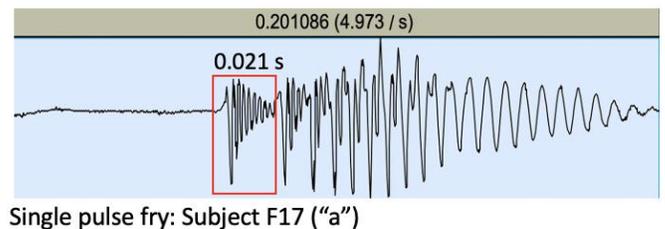
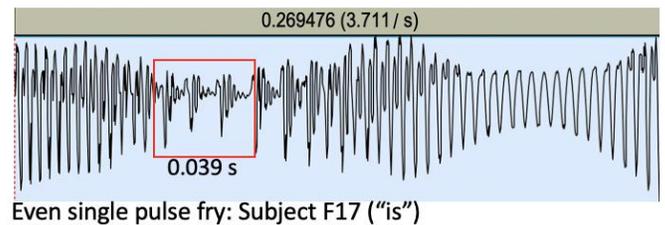
RESULTS

After careful examination of the instances of vocal fry produced by the 5 participants, the six categories of specific glottal fry patterns that emerged are:

- single pulse fry,
- double pulse fry,
- multiple pulse fry,
- delay fry,
- period doubling fry, and
- inaudible fry that you can “see but not hear.”

Category 1: Single Pulse Fry

Single pulse fry occurs when there is only one pulse (i.e., one negative acoustic pressure transient) per vocal fry period. Single pulse fry can be separated into two distinct subcategories: *even single pulse*, and *uneven single pulse*. Even single pulse fry is a specific type of single pulse fry in which the pulses are spaced out relatively evenly (meaning that the length of damping between pulses are of similar duration,) and have



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similar amplitudes. Uneven single pulses differ in the sense that they often have differing amplitudes of pulses or have inconsistent durational spacing. It is important to note also that “single” in single pulse fry describes the number of pulses per period of vocal fold vibration, which is one. However, there can be a number of single pulses occurring in a row.

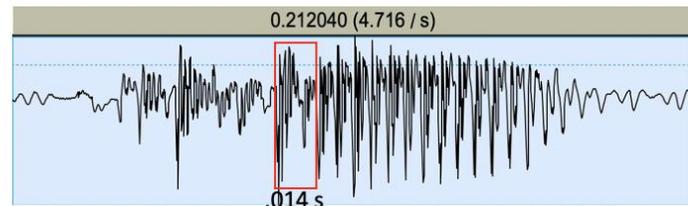
Category 2: Double Pulse Fry

Double pulse fry occurs when there are two pulses per period of vocal fry production rather than just one. There are subcategories for this type of fry as well, and these include double

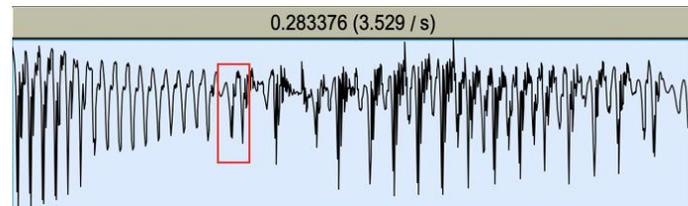
pulse with a primary (first) and secondary (second) negative pressure transients, double pulse with a secondary (first) and primary (second)

negative pressure transients, and double pulse with both primary negative pressure transients. Double pulse with a primary-then-secondary pulse describes a type of double pulse fry in which the first pulse has a greater amplitude (lower transient acoustic pressure spike) than the

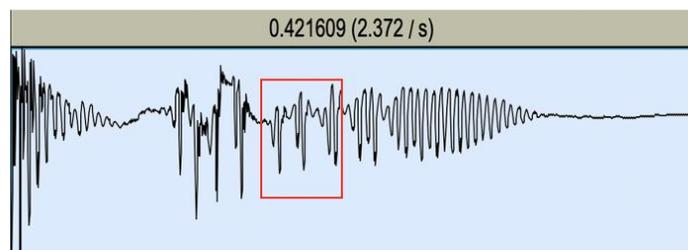
second. Double pulse with a secondary-then-primary pulse differs in that this type of fry consists of a weaker first pulse and a stronger second pulse (with a greater amplitude). Double pulse with a primary-then-primary pulse simply means that both pulses are of equal amplitude.



Double pulse fry (primary, secondary): Subject F15 (“at”)



Double pulse fry (primary, primary): Subject F19 (“end”)

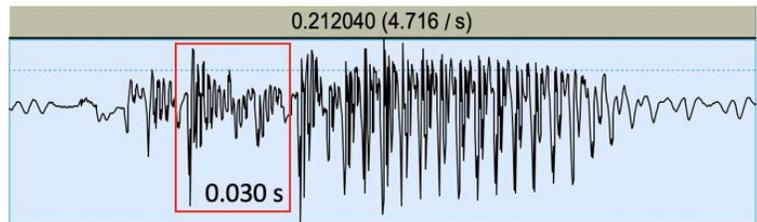


Double pulse fry (secondary, primary): Subject F19 (“zon”)

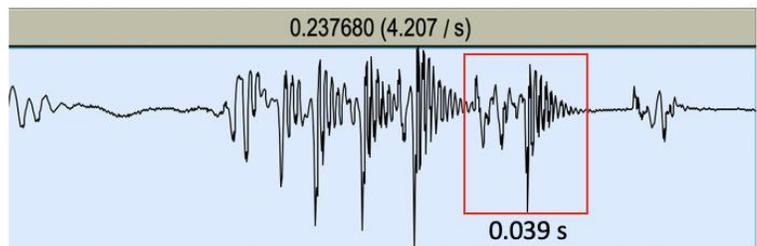
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Category 3: Multiple Pulse Fry

Multiple pulse fry is any type of vocal fry with three or more pulses occurring per one period of vocal fry production. In the case of this research study, the only instances of multiple pulse fry that were observed consisted of three pulses occurring in one period, and there were relatively few of these



Multiple pulse fry: Subject F15 ("at")

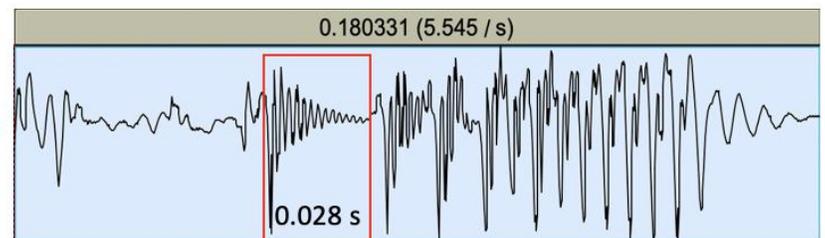


Multiple pulse fry: Subject F15 ("it")

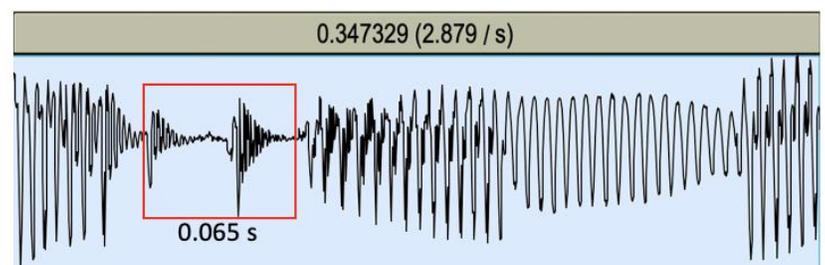
instances. However, it is completely possible to have more than just three pulses occurring in one period. Work by Scherer (1989, 1990) has demonstrated that multiple pulse fry with three or more pulses per one period of vocal fold vibration can easily be produced in isolation, however the present study seemed to demonstrate that this pattern of vocal fry is relatively rare in running speech.

Category 4: Delay Fry

Delay fry is described by a pulse that seems to occur only at the onset of a vowel (syllable), and it was determined that in order to qualify as delay fry, there must be a period of silence (vocal fold closure) between the initial pulse and the next



Delay fry: Subject F15 ("at")



Delay fry: Subject F17 ("end")

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excitation of at least 20 milliseconds. This duration may appear to be a somewhat arbitrary decision, because a delay of 20 ms, if it represented a series of single pulse fry patterns, would be a 50 Hz fry, which is not an unlikely frequency for fry on sustained vowels. However, it is a rare occurrence in the corpus of utterances in running speech produced by the 5 female participants, and is a relatively long duration compared to single pulse fry examples of this study, as well. [The decision of length may depend upon further analysis of male vocal fry instances, which may tend to be lower frequency values. It is possible that the delay fry may become a subcategory under single pulse fry if the occurrence is quite common in other speakers.] It is highlighted that the term “delay” refers to the observation that the larynx behavior at the beginning of a vowel appears to hyperadduct to cause one open-close gesture within one or two cycles with relatively long periods prior to releasing the adduction to produce more regular phonatory cycles at higher frequencies.

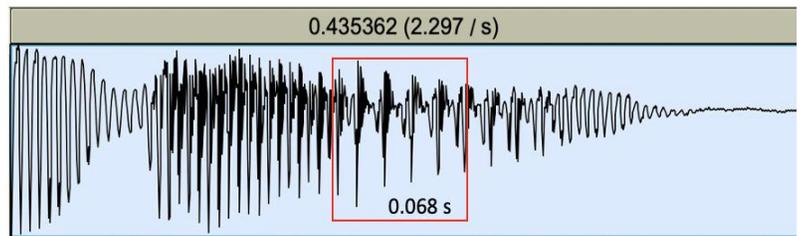
To summarize, delay fry is often seen as one pulse, a delay, and then another excitation that is typically either normal speech or a different pattern of vocal fry; however there can be multiple delay pulses as well. There were several instances of delay fry in this study that occurred as a pulse, a delay, another pulse, another delay, and then finally an excitation. These subcategories of delay fry were referred to as Delay 2 or Delay 3, and these numbers described the numbers of pulses with delays that existed before the next excitation.

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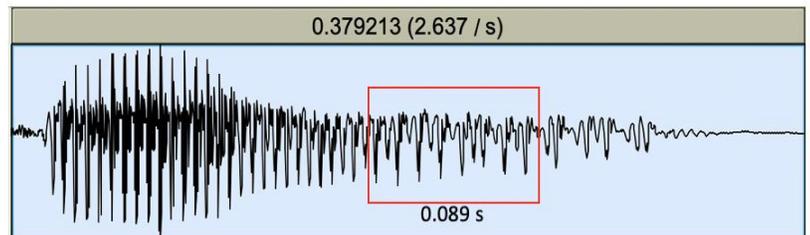
Category 5: Period Doubling Fry

Period doubling fry is a type of fry that is dependent on the presence of modal speech.

The term “period-doubling” describes the fact that this type of fry has a period that is twice as long as that of the *nearby* normal period of vocal fold vibration for the speaker. For example, if a female subject speaks at approximately 200 Hz, then that same speaker producing period doubling fry would do so at approximately 100 Hz



Period doubling fry: Subject F19 (“bow”)

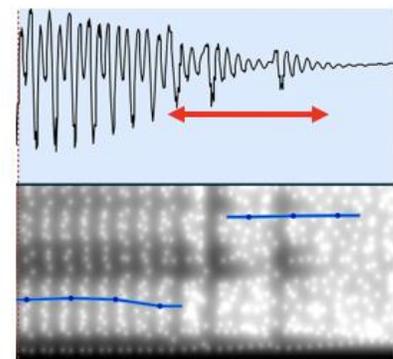


Period doubling fry: Subject F19 (“ors”)

(which is an octave below normal speech). The vocal fry is displayed on the spectrogram as having a “down, up, down” appearance. It is often called a “subharmonic” in the speech production literature, since it is typically approximately half the frequency of the normal speech nearby.

Category 6: Inaudible Fry

Another category of fry, one that is not completely understood yet, has been named “*inaudible fry*.” This particular type seems to be related to vocal fry in that there is present a significant acoustic transient and a relatively long period similar to other vocal fry types. This type was prevalent in two of the subjects in this particular study, and has presented as a fry-like



F11 – inaudible fry

utterance that was visible on the spectrogram, but not perceptual to the ear. The intensity of this

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type of fry is relatively lower than the sounds before and after it, and thus is difficult or impossible to hear. Thus, this is a more laryngeal-acoustic-based pattern that lacks perceptual reality. For this reason, it was unclear whether this category of fry would be considered vocal fry in the typical sense, and if it would have the same psychological and voice disorder consequences as the other types. It was, however, included in the final count.

Table 1. Types of vocal fry and their frequency of occurrence within the syllable (at the onset of the syllable, or earlier, later, or in the final position of the syllable).

	ONSET	EARLIER	LATER	FINAL	total	
Single pulse (SP)	14	4	6	11	35	
Even single pulse (ESP)	14	19	15	4	52	
Uneven single pulse (USP)	13	12	7	3	35	
Double pulse (DP)			1		1	
Double pulse, primary secondary (DP[p,s])	1		1		2	
Double pulse, primary primary (DP[p,p])	1		1		2	
Double pulse, secondary primary (DP[s,p])		1	2		3	
Period doubling (PD)	3	8	9	3	23	
Delay (D)	7				7	
Delay 2 (D2)	2				2	
Delay 3 (D3)	1				1	
Multiple pulse 3 (MP3)		1	2		3	
Inaudible (I)	6			2	8	
					174	total
Rough	3	3	1	1	8	
Glottal onset	4				4	

As displayed in the table, the total number of incidences of fry and rough voice, including a harsh onset, was 186. However, if only the vocal fry utterances are counted, the total number of incidences is 174. This study demonstrated that “single pulse fry” occurred most often in these

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speakers (with 122 occurrences), specifically “even single pulses” (with 52 occurrences). This was followed by “period doubling” (with 23 occurrences), and then by “delay fry” (with 10 occurrences) and “double pulse fry” (with 8 occurrences). The least common types of fry were “inaudible fry” (with 8 occurrences), and “multiple pulse fry” (with 3 occurrences).

This study also shown that fry tended to occur most often at the onset of syllables (62 times), followed by earlier in the syllable (45 times), followed by later in the syllable (44 times), and last, the final portion of the syllable (21 times).

DISCUSSION

Comparison of Vocal Fry Definitions

The definition of vocal fry register, which has been defined by various authors in the past, was re-evaluated for the purpose of this study and criteria were added to that definition. Contrary to the classic studies, the threshold for the production or perception of vocal fry does not appear to be 70 Hz. Typically, when the fundamental frequency shifted to an approximately octave lower, the perception was that of vocal fry. It is important to note that vocal fry also differs from creaky voice, which consists of a low frequency modulation of a normal speaking fundamental frequency. Vocal fry does not have this modulation, but instead has a characteristic damping (Keating, Garellek, & Kreiman, 2015). The last element of vocal fry has remained the same as that among the general research consensus: there is a longer period of glottal opening compared to a relatively short period of glottal closure.

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Comparison of Patterns Across Studies

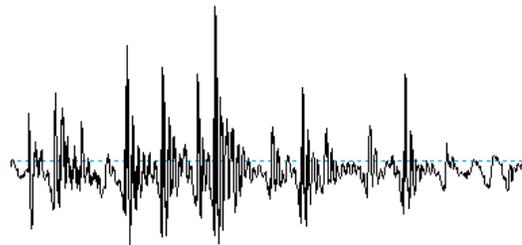
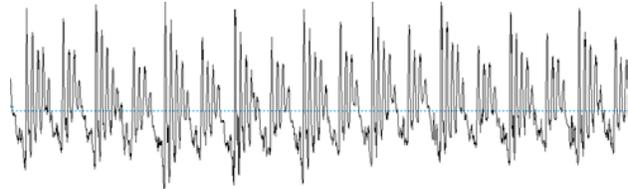
Past studies have attempted to note patterns in vocal fry productions. A study by Keating et al. (2015) uses the terms to describe creaky voice, including the term “multiply pulse voice,” which includes the category “double pulsing.”

Keating et al. (2015) used the term “double pulsing” interchangeably with “period

doubling.” Also in this study was the mention of

another type of creaky voice called “aperiodic voice.”

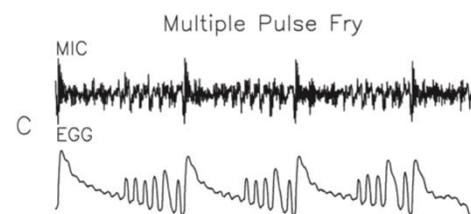
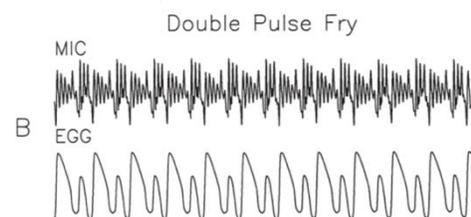
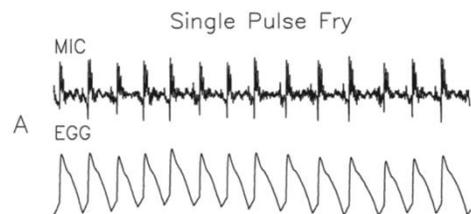
This particular category would correspond with what the present study suggests to be “uneven single pulses.”



Scherer (2017) described several types of vocal fry as well, using the terms “double pulse,” “single pulse,” and “multiple pulse.” These three categories were all used for the present study, although the “multiple pulse fry” example described by Scherer (2017) differs from the category of multiple pulse described in the present study.

Clinical and Sociological Relevance

The results of this study clearly demonstrate that single pulse fry is the most commonly observed category in these female subjects, and also that vocal fry is most likely to occur in the onset of a syllable. Although these



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subjects all have normal, healthy voices, it may be pertinent to conduct future studies on vocal fry specifically with subjects who demonstrate voice pathologies.

This study has raised several questions pertaining to the future of vocal fry research, particularly in a clinical aspect. It would be relevant to determine which patterns occur more frequently in vocal pathologies, as this could have diagnostic potential. Future research on this topic could focus more heavily on patterns of vocal fry that correspond to different laryngeal and physiological behaviors. Several questions may also be raised about the sociological implications of this study and the future research that may be conducted to clarify issues surrounding this. For example, perhaps specific patterns of vocal fry are perceived as more acceptable in certain contexts, and perhaps other patterns have more of a negative stigma attached.

Limitations

Some limitations to this study are that there was a small sample size of just young adult women. It would be important to study older individuals as well as those of different genders, in order to ensure that these categories are prevalent across other populations. Furthermore, this study only examined speakers in one particular region of the United States, and it may be beneficial to collect data from different regions in order to be able to generalize the results of this study. It is obvious that additional physiological and aerodynamic measures would help to explain the production aspects of vocal fry, and thus help lead to practical aspects of intervention for altering vocal fry behavior when appropriate.

CONCLUSION

Vocal fry is a complex, multifaceted phenomenon. The results of this study suggest that there are definitively types of vocal fry that also need to be differentiated physiologically. The

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types that were observed in this study are single pulse fry, double pulse fry, multiple pulse fry, delay fry, period doubling fry, and inaudible fry that you can “see but not hear.”

Further research is necessary to determine other potential categories of vocal fry, determine if there are individual idiosyncratic types of vocal fry, determine differences in vocal fry produced by males versus females, and research the physiological, acoustic, aerodynamic, and perceptual realities of each type.

Prior studies have pointed to a high usage of vocal fry among young adult women and potential negative consequences resulting from this, including negative perceptions from peers and employers. The nature of the current research is important to gather a basis of information that health professionals, such as speech-language pathologists, can use to help people who exhibit communication problems due to the use of vocal fry.

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