A CASE STUDY OF MENSTRUAL CYCLE EFFECTS: GLOBAL PHONATION OR ALSO LOCAL PHONATORY PHENOMENA?

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ABSTRACT

This study contributes to our understanding of two questions. Is global phonation (voice quality) affected by menstrual hormonal changes? Are the phonatory characteristics of phonologically voiced obstruents affected by menstrual hormonal changes? The paper presents a case study of 1 female recorded on a daily basis for a period of nine months. The material enabled analyses of global breathiness and other phonatory features of naturally produced vowels of Czech, and sustained vowels, and analyses of phonatory aspects of four Czech obstruents (/ʒ/, /ɦ/, /r̝/, [ʔ]). We find that global phonation is minimally affected by menstrual hormonal changes. Crucially, however, the phonatory properties of the obstruents can be subject to the effects of the menstrual cycle. Further research needs to establish how frequently this is observed in the general population.

Keywords: breathiness, voicing, glottalisation, menstrual cycle, phonation.

1. INTRODUCTION

There is some research that shows a. that female voices are perceived as more attractive when the conception probability increases [25], and b. that at least in the western world breathiness can function as a correlate of femininity and/or attractiveness [10, 12, 21]. This could originate in biomechanical biases: voice quality (global phonation) can be affected by a range of hormonal changes and, for these reasons, the larynx is sometimes considered a secondary sexual organ [2-3, 6, 10, 12]. Among these effects are also hormonal changes associated with the menstrual cycle. Interestingly, Premenstrual Syndrome (PMS) affects the cervix and the vocal folds in a comparable manner, and these physiological effects are also reflected in phonation [1]. More specifically, PMS can be associated with perceived breathiness [9] and higher jitter, and jitter can also be higher during ovulation [26]. Shimmer and HNR can, on the other hand, show the lowest values during ovulation [26]. Females who suffer from Premenstrual Voice Syndrome, and professional singers, are more likely show effects of menstrual hormonal changes on phonation [13, 19].

Whilst the existing studies point to the menstrual cycle having an effect on phonation premenstrually and during ovulation, they do not straightforwardly suggest that ovulation, as well as the period just before menstruation itself, should necessarily be associated with increased *breathiness*, as jitter and shimmer differences can reflect other aspects as well.

Could such effects of the menstrual cycle extend to other phenomena whose production relies primarily on the larynx, and which contribute to the phonetic implementation of phonological contrasts? Indeed, [30-31] found that the contrastiveness of VOT, whereby /p, t, k/ and /b, d, g/ are distinguished in English, is “enhanced at the high hormonal phase of the menstrual cycle” [30, p. 21], by 1.39-3.51ms (based on [30, p. 22]). In this light, the present study asks the following questions:

- Is global phonation affected by menstrual hormonal changes?
- Are the phonatory characteristics of obstruents affected by menstrual hormonal changes? If so, are the effects bigger for allophonic rather than phonemic categories?

Although the first question has been asked previously (see above), the focus across studies is not always on the same phases of the cycle, nor is the cycle divided into comparable periods across studies. Furthermore, the calculation of the relevant phases also tends to differ, as do assumptions as to how long a cycle of a healthily menstruating female is. This makes a direct comparison of the available studies somewhat challenging (A bit more on this in 2.7.).

2. METHODOLOGY

2.1. Subject

The author conducted a case study of 1 female (F) who met the criteria of a suitable subject:

- F is a healthily menstruating female
- F has never been on contraceptives or any hormonally based medication
- F has never been pregnant or lactating
- F has never smoked
- F does not drink alcohol
- F was not aware of the number and the characteristics of the menstrual phases during

the recording stage of the project; this factor cannot be underestimated, since F is the author of this case study; I only consulted the literature on the individual phases after data collection

- F does not have any known allergies
- F is not a professional singer
- F is not aware of suffering from PMS

F was 29 years old during the data collection (2017).

2.2. Recording procedure

F was recorded once a day for a period of time which resulted in 262 successful recording days. The recording did not take place when F suffered from a cold, could not participate, forgot, felt unusually fatigued, was exposed to cigarette smoke, or due to technical issues. F was recorded wearing the head-mounted AKG C520 microphone in conjunction with H5 Zoom recorder.

2.2. Materials

F was recorded producing the following:

- phonologically short vowels of Czech twice during each session ([a], [ɛ], [ɪ], [o ~ ɔ ~ ɒ], [u])
- phonologically long vowels of Czech sustained for 5s and for maximum phonation time ([aː], [ɛː], [iː], [o ~ ɔ ~ ɒː], [uː])
- the sentence *Řekni, řekni, Řehoři, že v řece plují úhoři.* "Say, say, Gregory, that there are eels swimming in the river."

The sentence contains 6 instances of /r̝/, and 1 instance of /ʒ/, /ɦ/, and [ʔ] each. This yielded a corpus of 2606 short vowels, 1283 sustained long vowels, 1293 long vowels sustained for 5s, 1564 /r̝/'s, 260 /ʒ/'s, 517 /ɦ/'s, and 260 [ʔ]'s. These obstruents differ in their phonological characteristics. Firstly, voicing is a very important cue of the /ʒ/-/ʃ/ contrast (although see [22]). /ɦ/ is traditionally described as voiced, but importantly it does not contrast with */h/ in Czech. /r̝/ has a voiced as well as a voiceless allophone ([16], see also [15]). [ʔ] is found word-initially when the first segment is a vowel (e.g. *úhoři*) and is not considered contrastive (Although compare *Byla naivní* "She was naive" [naɪvɲiː] with *Já byl na i v ní* "I was both on and in her" [naʔɪvɲiː] [18]).

2.3. Segmentation of vowels

Each vowel was segmented manually in Praat [5]. The onset of the vowel was established as the onset of energy increase, caused by one or more of the following: periodic signal commences, vowel-initial glottalisation (glottal attack) commences, glottal friction commences. The offset of the vowel was established as the offset of energy present in the signal. This could be the end of periodic signal, glottalisation, and voiceless glottal friction. However, a more detailed segmentation was carried out on top of this basic segmentation. Firstly, any instances of glottalisation (see 2.4.), voiceless glottal friction, and periodic intervals within the vowel were annotated. This was done in order to establish to what extent any potential variation in breathiness is due to variation in the periodic part of the vowel.

2.4. Glottalisation

Glottalisation was defined either as irregular vocal fold vibration, visible in the signal as an interval of irregularly timed glottal pulses, or as an interval of a sudden drop of f_0.

2.5. Breathiness

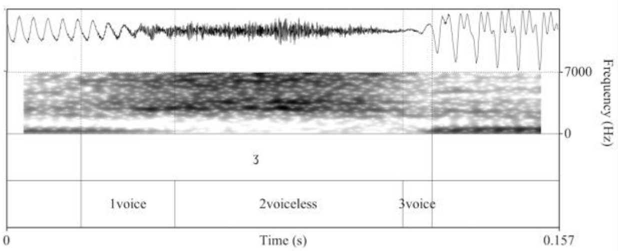
Breathiness was quantified via Cepstral Peak Prominence (CPP [e.g. 8, 14]) in VoiceSauce [27-28] and Matlab [23]. This measure was selected because it has been found to be a very reliable correlate of perceived breathiness [14]. The lower the CPP, the breathier the signal. Only the mean CPP results are reported a. for the entire vowel interval (including glottalisation and voiceless friction) and b. for only the periodic interval of the vowel. If interested in more details, contact the author.

2.6. Obstruent voicing

/ʒ/ was identified on the basis of the onset and offset of oral friction, present in higher frequencies in case of this fricative. This was also one of the criteria used to identify the onset and offset of /r̝/; however, utterance initially, occasionally the onset of the oral friction followed the onset of voicing. In these cases, it was the onset of voicing that was used to establish the onset of the fricative. /ɦ/ was the most difficult obstruent to segment: F's phonation is fairly breathy and the vast majority of her /ɦ/'s are voiced.

As shown in Fig. 1., the presence of voicing in these two obstruents was established on the basis of the onset of a quasi-sinusoidal shape of the waveform. Raw duration of voicing was extracted in Praat, and normalised as a proportion of the obstruent interval (e.g., 65% of obstruent X is voiced, and 65% may present one uninterrupted interval of voicing or a sum of e.g. two intervals of voicing that are separated by an interval where no voicing takes place).

Figure 1: Identifying voicing in obstruents.



In addition, analyses of the realisation of the V+V [ʔ] were also carried out. Three realisations were distinguished: a. absence of glottal stop; b. periodic creak (i.e. drop in f_0, but not absence of periodicity); and c. aperiodic creak (i.e. both drop in f_0 as well as absence of periodicity).

2.7. Menstrual cycle phases

The three *ovarian* menstrual phases were of interest in this study: the follicular phase, ovulation, and the luteal phase. The number of phases to work with does not seem to have been agreed on in the literature, however [e.g. 24, pp. 87-93, 25-26; 9, pp. 190]. Furthermore, not all researchers approach ovulation as lasting e.g. 1 day (e.g. [17, p. 53]). The overview of F's menstruation and the calculations can be found here: https://tinyurl.com/y5fh8mcz. Table 1 shows the number of segments available per phase:

Table 1: Number of vowels and obstruents by ovarian phase.

Segment	Follicular	Luteal	Ovulation
Vowel	2,375	2,657	161
/ɦ/	247	254	16
/ʒ/	124	128	8
/r̥/	749	767	48
[ʔ]	124	128	8

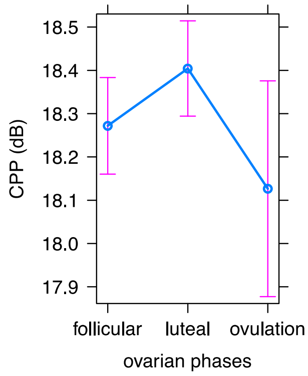
3. RESULTS

Graphs and statistical analyses were done using R with RStudio [29], with the following packages: *lme4* [4], *lmerTest* [20], *effects* [7]. In the statistical analyses, menstrual phase was a fixed effect, recording day was a random effect, and the dependent variable was (sub)segment specific.

3.1. Global phonation

Fig. 2 shows that ovulation is associated with the lowest CPP values, i.e. with the highest breathiness, and the luteal phase is the least breathy. However, only the latter comparison is confirmed by the statistical analyses (all comparisons of vowels with short /a/ were significant ($p < 0.0001$); follicular phase vs ovulation: $\beta = -0.1454$, SE = 0.12157, $t = -1.196$, $p = 0.232$; follicular phase vs luteal phase: $\beta = 0.1323$, SE = 0.0422, $t = 3.135$, $p < 0.01$).

Figure 2: CPP (entire vowel) and ovarian phases.

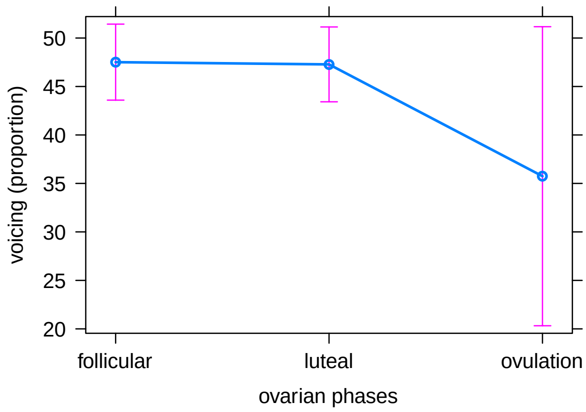


In contrast, although visual inspection reveals that ovulation is still associated with the lowest CPP across vowels when only periodic portions are analysed, this is not confirmed by the statistical analyses, which show an effect of the segment, but not that of menstrual phase (all comparisons of vowels with short /a/ were significant ($p < 0.0001$); follicular phase vs ovulation: $\beta = -0.12083$, SE = 0.13005, $t = -0.929$, $p = 0.353$; follicular phase vs luteal phase: $\beta = -0.0514$, SE = 0.05064, $t = -1.015$, $p = 0.31$).

3.2. /ʒ/ voicing

48% of /ʒ/ is voiced in the follicular phase, 47% in the luteal phase, and 36% in the ovulatory phase (Fig. 3).

Figure 3: Voicing in /ʒ/ and ovarian phases.

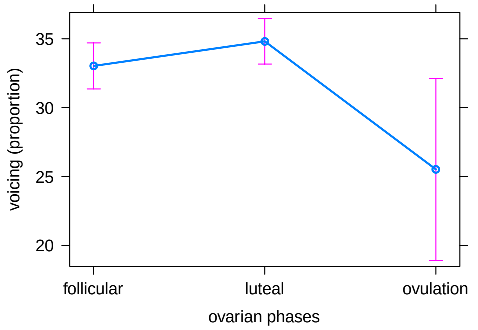


Although this visual inspection confirms the hypotheses, the results are not confirmed by the statistical testing (follicular vs ovulatory phases: $\beta = -11.769$, SE = 8.079, $t = -1.457$, $p = 0.146$; follicular vs luteal phases: $\beta = -0.233$, SE = 2.791, $t = -0.083$, $p = 0.934$). This may be due to the low number of data points for ovulation.

3.3. /ɽ̤/ voicing

33.03% of /ɽ̤/ is voiced in the follicular phase, 34.82% in the luteal phase, and 25.52% in the ovulatory phase (Fig. 4).

Figure 4: Voicing in /ɽ̤/ and ovarian phase.



The visual inspection as well as the statistical analyses reveal that the phoneme is realised with less voicing during ovulation than the other two phases (follicular vs luteal phases: $\beta = 1.7897$, SE = 1.1988, t = 1.492, p = 0.1357; follicular vs ovulatory phases: $\beta = -7.5074$, SE = 3.4746, t = -2.161, $p < 0.05$).

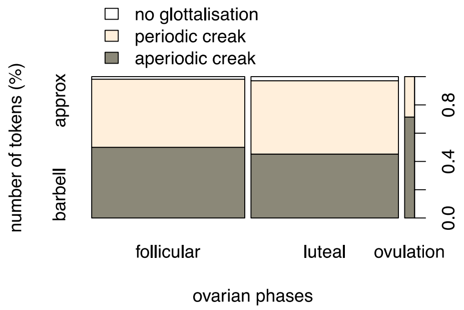
3.4. /ɦ/ voicing

As could be expected in case of word-internal intervocalic /ɦ/, the vast majority of the cases are indeed fully voiced. The devoiced instances are associated with the follicular and the luteal phases: 99.68% of /ɦ/ is voiced in the follicular phase, 98.86% in the luteal phase, and 100% in the ovulatory phase. The statistical analyses not surprisingly reveal no significant differences between the phases (follicular vs luteal phases: $\beta = 0.812$, SE = 0.4463, t = 1.82, p = 0.0694; follicular vs ovulatory phases: $\beta = 1.1367$, SE = 1.2883, t = 0.882, p = 0.378), although the comparison between the follicular and luteal phase approaches significance, with the follicular phase showing least voicing.

3.5. Implementation of V+V [ʔ]

Úhoři occasionally does not show any V+V [ʔ]: 2% of cases occur in the follicular phase, 3% of cases in the luteal phase, and none during ovulation. Interestingly, aperiodic creak occurs more frequently during ovulation (71%) than during the follicular phase (50%) and the luteal phase (45%). These trends can be seen in Fig. 5. However, the statistical analysis does not suggest a significant effect of the ovarian phase on the realisation of glottalisation (follicular vs luteal phases: $\beta = 0.1944$, SE = 0.278, z = 0.698, p = 0.485; follicular vs ovulatory phases: $\beta = -0.9248$, SE = 0.87, z = -1.063, p = 0.288).

Figure 5: Phonetic types of [ʔ] and ovarian phase.



4. DISCUSSION

This study has asked two questions. Firstly, is global phonation affected by menstrual hormonal changes? We find that the vowels produced by F are visually the breathiest during ovulation as opposed to the follicular and the luteal phases. However, this is not exactly borne out by the statistical analyses: it is only when the entire vowel (including glottalisation and voiceless glottal friction) is included in the analyses that the follicular phase emerges as significantly conditioning more breathiness than the luteal phase, but no differences vis-à-vis ovulation are significant. Secondly, are the phonatory characteristics of obstruents affected by menstrual hormonal changes? Yes, phonatory properties of obstruents *can* be affected by the menstrual cycle. Namely, differences may be observed between the ovulatory phase in contrast to the follicular and luteal phases.

Finally, I asked whether any potential effects related to phonatory properties of obstruents are bigger for allophonic rather than phonemic categories. It is indeed /ɽ̤/ whose voicing characteristics are significantly affected by menstrual phase: the amount of voicing produced in this consonant is the least during ovulation as opposed to the follicular and luteal phases. Whilst the visual inspection of the voicing properties of /ʒ/ show a similar trend, this is not confirmed by the statistical analysis. However, this may be due to the fact that although 48 /ɽ̤/'s were collected during the ovulation phase, only 8 /ʒ/'s were. Finally, visual inspection suggests that a V+V glottalisation may be more aperiodic during the ovulation phase, although this is again not confirmed by the statistical analysis.

In line with [30-31] I conclude that investigating the role of the menstrual cycle in the variation found in (sub)segmental laryngeal phenomena is an interesting and potentially important avenue to pursue. Future research in this area however has to address the diversity of approaches to establishing the phases of the cycle, and crucially needs to target a large portion of the general population, and a range of languages.

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