MUSICAL ASPECTS OF VOWEL FORMANTS IN THE EXTREME METAL VOICE

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ABSTRACT

In place of the pitched singing found in most genres of Western popular music, extreme metal vocalists use specialized screaming techniques that emphasize timbres associated with aggression, anger, power, alarm, and other emotionally charged utterances. Largely because these techniques resist established methods of music analysis, scholarly writings on heavy metal music have not yet acknowledged several of the most important acoustical and expressive features of the extreme metal voice. Using spectrograms generated with AudioSculpt, a powerful sound analysis, processing, and re-synthesis program, this paper argues that the acoustical properties of vowel formants serve a primary expressive role in enhancing the uncanny timbral qualities of extreme metal vocals.

We begin from the performer's perspective, addressing the physiological mechanisms involved in the production of extreme metal vocals as well as their primary acoustical characteristics. Because, as we argue, the formant frequencies of vowels are amongst the most important—and under-researched—of these, we demonstrate in two separate contexts how vocalists have sacrificed the intelligibility of their lyrics by expressively altering their vowels. Finally, to demonstrate further expressive resources used by extreme metal vocalists, we show how rapid and large fluctuations in a first formant frequency envelope support arguments made by Williams and Stevens (1972) on the acoustical correlates of emotions and speech.

1. INTRODUCTION: THE EXTREME METAL VOICE

Vocalists in extreme metal, a group of particularly aggressive sub-genres of metal music such as death metal and black metal, typically avoid pitched singing in favour of specialized screaming techniques. Because extreme metal vocalists cannot draw upon melodic-harmonic resources for musical expression, they instead place special emphasis on several common techniques that have thus far escaped the attention of popular music scholars, including those who specialize in metal. In addition to placing special importance on musical timbre, the most prominent of extreme metal vocal resources include the use of the ventricular folds, two contrasting methods of generating air flow through both inhalation and exhalation, ways of altering the length of the vocal tract, and the acoustical properties of vowels.

1.1. Basic Techniques for Vocal Production

In place of the vocal folds, which vibrate to produce pitched singing or voiced speech, extreme metal vocal screams draw upon the ventricular folds (or "false vocal chords"), covered by a mucous membrane and located a few millimetres above the vocal folds [1].[2] This allows extreme metal vocalists to generate a wide spread of spectral energy often described as unpitched screaming or growling (for example, [5]).

The airflow which passes through the ventricular folds can be produced through inhalation or exhalation depending on the performer's stylistic preferences or the particular musical context of a passage [7]. Each method has distinct advantages and drawbacks for the performer. Typically, exhaled screams achieve greater volume than inhaled vocals but this is not necessarily an advantage given the availability of microphones; the additional force generated by exhaled screams can be especially taxing on the performer and be more damaging than inhaled screams. Another trade off involves vocal agility and the ability to articulate consonants. Inhaled vocals tend to be more agile with rapid variations in register shifting and movement between vowels. However, inhaled screams depend on a steady "sucking" inflow of air that prevents the kinds of clear consonant articulations that are possible with exhaled screams. Exhaled vocals can be more effective in contexts where it is advantageous to hear lyrics such as the screaming of popular song titles in live settings. Conversely, inhaled vocals are especially useful for vocalists who scream in especially high registers or in climactic sections where spectral energy reaches upwards of 4000Hz, a region where high concentrations of spectral energy are generally less present with exhaled screams [7].

1.2. The Role of the Vocal Tract

Once an extreme metal vocalist has produced a spread of spectral energy with the ventricular folds, there are several ways in which the vocal tract can be lengthened or shortened to enhance that sound. One can simply tilt the head forward, lowering the jaw, a common technique in death metal that results in a lower sounding scream. Such a movement occurs naturally in speech, for instance, when one attempts to produce an exaggeratedly "macho" voice. Conversely, one can tilt the head upwards to shorten the vocal tract length to produce a higher voice. The larynx can also be raised or lowered, a process that also occurs naturally in speech, depending on whether a higher or lower voice is at-

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[2] Although the use of the ventricular folds remains to be proven, writers on the extreme metal voice appear to have reached a consensus on their use [2, 3, 4], perhaps owing to the demonstrated involvement of the ventricular folds in comparable vocal styles such as Kargyraa throat singing [5].

tempted. Finally, the lips can be spread or rounded to shorten or extend the length of the vocal tract (see Figure 1).

Figure 1: *Rounded (left) and spread (right) lips to alter the length of the vocal tract.*

This is not to say that vocalists consciously focus on manipulating their vocal tracts when they perform. Instead, an extreme metal vocalist needs only to concentrate on a desirable powerful and deep or shrill and piercing scream and the physicological movements described above will occur more or less automatically. Perhaps the most basic and suggestive characterization of the extreme metal voice is to think of it as a physiological imitation of a large beast. The ventricular folds create a spread of spectral energy characteristic of an inhuman sound source, while each of these methods for changing the vocal tract length (especially those that lengthen it) exaggerates the impression of its size.

1.3. The Role of Vowel Formants

The growl effect produced by this characteristic spread of spectral energy is widely discussed in literature on metal and we consider it to be a fundamental trait of all extreme metal vocals. Much less obvious yet arguably equal in musical importance are the acoustics of vowel formants. Indeed, the phonetic analysis of vowels may prove to be one of the most powerful resources for understanding and analyzing musical expression in the extreme metal voice.[3] When vocalists sacrifice the intelligibility of their lyrics in order to enhance the depth or piercing quality of their screams, they are essentially altering the acoustical properties of their vowels to sound heavier or more shrill. Each of the physical descriptions given above can be thought of as ways of producing and exaggerating vowel sounds, making the tools and methods that linguists have developed to study speech extremely useful for developing a much more nuanced understanding of how extreme metal vocalists achieve their effects.

International Phonetic Alphabet (IPA) vowel symbols thus become short-hand for the formant frequency regions within which extreme metal vocalists scream (not unlike chord symbols for charting pitch combinations) and the IPA vowel diagram provides a space for charting how extreme metal vocalists expressively stray from the expected formant regions of their lyrics. Spectrograms, which linguists have used for decades to study speech, provide visual cues for drawing attention to details in these vocals that might ordinarily be missed. This paper will apply these tools, demonstrating in two contrasting contexts the central importance of vowel characteristics in extreme metal vocal expression. Lastly, a final example will demonstrate the utility of spectrograms as a way of closely investigating emotional expression in extreme metal vocals.

[3] Of course, the acoustical properties of vowel formants play an expressive role in operatic and other forms of singing as well [1], although we would argue that their importance in extreme metal is especially acute given that extreme metal screams do not draw upon pitched melodies for expression.

2. VOWEL FORMANT ALTERATIONS

One way to examine the extent to which vocalists expressively alter the frequency levels of vowel formants is to compare how different vocalists pronounce identical lyrics while performing. Based on examining recordings of one of the author's (Smialek) own vocal techniques, we would expect most vocalists would make slight to drastic distortions of vowel content depending largely on musical context. If a vowel such as /u/ (as in "who") has the lowest recognizable first and second formant frequencies of vowels in American English, a death metal vocalist should be able to sacrifice the intelligibility of a vowel such as the /ʌ/ in "blood" so that it can instead sound lower and thus heavier: /blʌd/ becomes /blud/. Conversely, a black metal vocalist aiming to provide a piercing screech might take a vowel like the /o/ in "soul" (/soʊl/) and raise its component formants to sound a brighter /a/, perhaps only momentarily as in /saol/ (with a lingering scream on the /a/ segment).

2.1. Expressive Alterations to Vowel Formants in "God"

In order to explore these possibilities, we invited a volunteer vocalist to be recorded in The Critical Listening Lab, a soundproof laboratory that permits recording with minimal reverberation housed at the Centre for Interdisciplinary Research in Music, Media, and Technology (CIRMMT) at McGill University. We asked the volunteer vocalist to perform the word "god"—a frequently recurring term in both death and black metal—in five different ways so that his formant frequencies could be compared with those of vocalists on existing studio recordings. Figure A1a displays a first glimpse at some spectrograms of the volunteer's recordings.[4]

2.1.1. Analyzing the Synthesized Vowels

Comparing Figure A1a with the frequency values listed for the volunteer vocalist in Table 1 allows us to make a number of observations about how a vocalist can substantially alter the vowel content of a word, in this case "god," to create expressive variation.[5] Utterances 1 and 2, both spoken with an ordinary speaking voice, act somewhat as control conditions, with the formant frequencies in Utterance 2 virtually matching the accepted standard for the American English values of the vowel /ɑ/ [11]. By comparison, Utterances 3 and 5, which are both exhaled, are significantly lower, especially with respect to their first formants. They also both involve changes in formant quality: a subtle shift in the lower formant for Utterance 3 and a complete shift in vowel content between the neighbouring /ɑ/ ("god") and /ɔ/ ("gawed") vowels. Finally, the inhaled Utterance 4 exhibits the most substantial movement, shifting between the high vowels /æ/ ("gad")

[4] Because the first two samples (marked 1 and 2) were spoken too quickly to be visible at the resolution shown in Figure 2, the time axis for those utterances were expanded to bring its shape into relief (see Figure A1b).

[5] Table 1 may be accessed at http://www.music.mcgill.ca/~depalle/Dafx12/metalVoiceDafx12.html (accessed 13 April 2012). The Cradle of Filth examples in the table are taken from [10].

and /ɑ/ ("god").[6] Figure A1c indicates these shifts by displaying vertical "markers" generated in AudioSculpt overtop of Utterance 4; by tracking sudden excitations or depletions of energy, the markers indicate moments of vowel change when their maximum threshold value is sufficiently reduced.

Each of these vowel alterations either depart from or return to the vowel placement one would expect in the word "god" and, by occurring on both the brighter and darker sides of the vowel, indicate how a vocalist could slightly alter the formant quality of a word to achieve a more piercing screech or a deeper growl.

2.1.2. Vowel Alterations on Commercial Recordings

Moving from a relatively controlled laboratory context to the more musical context of a widely-circulating studio recording, Table 1 compares several samples of the word "god" uttered in different ways by different extreme metal vocalists. As we have found with the volunteer's five utterances of the word "god," each of the diverse vocalists widely differ in their manipulations of the vowel /ɑ/. Amongst the vocalists sampled, Steve Tucker of Morbid Angel demonstrates the greatest consistency in his vowel content, always darkening his vowel to place his formants in between the values of /ʊ/ and /ɔ/ [12]. As one can see from a spectrographic comparison of his voice juxtaposed with the voice of George "Corpsegrinder" Fisher of Cannibal Corpse given in Figure A2, the formants in Tucker's voice are quite easily discerned compared to the inconclusive lower formants of Fisher's voice [13]. In Fisher's case, his second formant appears spread throughout the 1000–1500Hz range while the first appears to be much lower in the region of 100Hz. While acknowledging that one cannot distinguish with certainty between the spectrographic image of Fisher's first formant and the guitars playing at the same time, it seems likely that the guitar is blending with the voice in the same frequency region.

2.1.3. Aurally Confirming Spectrographic Analyses

In instances such as these, we have found it useful to check our aural impressions of the vowel content with formant synthesizer programs. A program such as Jonas Beskow's Formant Synthesis Demo can generate white noise (among different other waveforms) and apply a filter to it in the shape of vowel formants.[7] The result sounds very much like a slightly distorted whisper and can approach the sound of a death metal voice surprisingly well. Since the interface includes a formant chart plotting first and second formants against one another as well as individual sliders for formant frequency and bandwidth, one can easily test the sound of hypothetically placed vowel formants and verify the acoustical accuracy of one's aural impressions from a recording. We followed this procedure often when compiling Table 1, allowing us to be confident in our vowel measurements even when the formant locations were difficult to extract in a spectrogram.

2.2. An Application to Music Analysis Using a CD Excerpt

Since we have detailed some observable acoustical features of a vocalist sampled outside of extreme metal's more usual musical contexts, it will be valuable to more closely examine the extreme metal voice as it exists in currently circulating metal recordings first with a brief clip from a song by Morbid Angel titled, "He Who Sleeps" [12]. An especially slow track (51bpm) on a concept album centred on the hidden power of dormant gods, this track seems particularly appropriate to explore the vocal-acoustical correlates of heaviness in death metal. We've already noted how Steve Tucker (Morbid Angel's vocalist on "He Who Sleeps") consistently produces lower than usual formant frequencies when voicing the /a/ in "God." What makes this excerpt especially revealing is that it contains the /a/ vowel within a diphthong, specifically as the first half of /aɪ/ in the word "lives." Furthermore, it uses hard panning to present the word "lives" multiple times as Tucker's voice enters three times in different speaker channels. How is this vowel presented within this more complex musical context?

2.2.1. Vowel Transitions through a Diphthong

Let us begin with the leftmost box in Figure A3. This box encapsulates the final word of the phrase "Curse your empty lives," which enters in both channels simultaneously (the spectrogram of the left channel is shown directly above the spectrogram of the right channel). Compared to the second entrance of the word "lives" that occurs about a second later in the left channel only, this first entrance moves quite quickly between the /aɪ/ vowels. After the onset of /l/, the two lowest formants narrow to the characteristically close first- and second-formant position of /a/ (this occurs at the 146 second mark). Almost immediately the two formants spread outwards from one another as the second formant climbs to its peak position in /ɪ/. Such a quick vowel transition through the diphthong resembles spoken speech so that one can hear the lyrics relatively clearly.

By contrast, the second and third vocal entrances abandon the clarity of the lyrics for a much more dramatic sustained scream, appearing first in the left channel and then again in the right. What is significant here is how this time the vocalist lingers on the vowel /a/ for nearly the entire the scream, only sounding the outward spreading phonemes of the vowel /ɪ/ at the last possible moment. Considering that it would be possible to give a convincing long scream with an earlier vowel transition, it seems to me that this is an instance where the substantially lower second formant in /a/ is used to produce a darker overall vowel than the brighter /ɪ/ and thus a heavier sound.[8] The spectrograms provide a vivid representation of how those contrasting vowels are used to heighten the drama of the lyrics.

3. EMOTIONAL NUANCES IN EXTREME METAL VOCALS

Considering the importance of vowel characteristics in the emotional drama of a song, it is fruitful to ask what other acoustical

[6] For a more extensive discussion of how inhaled and exhaled vocals appear differently in spectrograms, see [7].

[7] The program is available for a free download at http://www.speech.kth.se/wavesurfer/formant/ (accessed 21 May 2010).

[8] Our thanks go to Prof. Michael Wagner of McGill University's Linguistics department for altering us to the possible objection that this diphthong transition, lingering on /a/ rather than /ɪ/, is normal in English prosody and could consequently be seen as less musically expressive than if the vocalist were to violate prosodic norms. We maintain that the vocalist's accordance with prosodic norms does not diminish the musical impact of lingering on the lower formant frequencies of /a/, an acoustical effect which we argue significantly contributes to the excerpt's sense of power or "heaviness."

aspects of the extreme metal voice contribute to a song's sense of emotional poignancy. In the same way that spectrographic studies of speech vowels can inform research on the extreme metal voice, we might generate some inferences about extreme metal vocals and emotional expression using an intriguing study done in the 1970s on the acoustical correlates of emotional signifiers in speech.

3.1. F_0 Contours and Emotional Speech

Focusing on the fundamental frequency contours of both actors acting out fear, sorrow, anger, and neutral speech as well as pre-existing samples of individuals known to have felt those emotions while talking, Carl E. Williams and Kenneth N. Stevens generated the following comparative table of fundamental frequency contours which they believed to be representative of specific emotions (see Figure 5) [14].

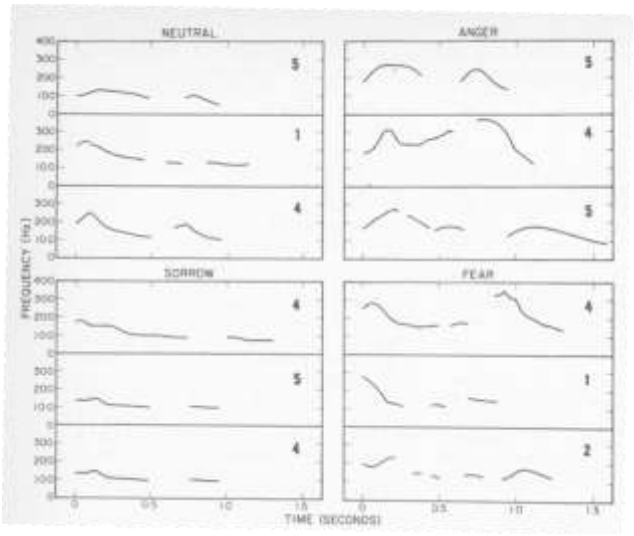

Figure 5: *A Reproduction of Williams and Stevens' Fig. 1 showing fundamental frequency contours for various emotions in different control conditions.*

Although their results are somewhat tentatively received in the literature, the basic claims made by Williams and Stevens towards fear and anger seem instructive for how the extreme metal voice is able to communicate specific emotions.[9] Often, but not always, the speech samples Williams and Stevens took showed "peaks in the F_0 that were much higher [for fear] than those encountered in a neutral situation." Two such peaks are especially evident in their condition no. 4 for fear reproduced in Figure 5 (see the top row in the bottom-right corner of the figure). Similarly, they reported very high fundamental frequencies on a consistent basis for anger, concluding that the "range of F_0 observed for utterances spoken in anger situations was also considerably greater than the range for the neutral situations."

[9] In his literature review of research on emotion as expressed by the voice, Klaus R. Scherer calls the results in Williams and Stevens' study "encouraging," but warns that "[t]here is a serious possibility that the essentially atheoretical approach adopted in most encoding studies may prevent the accumulation of a body of systematic knowledge of the effect of emotional states on a variety of vocal characteristics in spontaneous speech" [15].

3.2. Emotional Expression in At the Gates' "Cold" (1995)

Upon first encountering Williams and Stevens' study, one of the authors (Smialek) immediately thought of the vocals of Tomas Lindberg which he had always considered to be uniquely strident in emotion. One excerpt from the song "Cold" in particular, taken from the band's most widely recognized album *Slaughter of the Soul* (1995) struck him as particularly poignant and he was eager to see if spectrograms might reveal an aspect of the song's appeal [16]. With the formant shifting techniques of Mongolian and Inuit throat singers in mind, we wondered if a similar control over the movements of individual vocal formants might be at play here.

3.2.1. Comparing Periodic and Noisy signals

It is worth first addressing a possible methodological problem with comparing a spectrogram of "Cold" with Williams and Stevens' spectrograms of speech. In order to produce a spectrogram of "Cold" with similar settings to those of Williams and Stevens, one might begin by generating a narrowband spectrogram of "Cold" as Williams and Stevens had done. This would ostensibly produce an image of the extreme metal voice with a fundamental frequency contour that could be compared to the speech contour they studied. However, unlike the periodic signal generated by voiced speech, which reveals vocal formants in a broadband spectrogram and individual harmonics in a narrowband display, the aperiodic "noisy" signal of the extreme metal voice appears virtually identical when it is displayed in either format. That is, its narrowband representation shows formant contours instead of harmonics because the extreme metal voice is characterized by a spread of spectral energy rather than the regularly spaced harmonics characteristic of a periodic signal like voiced speech.

Rather than invaliding the comparison, this difference in periodic vs. noisy signals suggests that both a narrow- or broadband spectrogram of "Cold" can be usefully compared with the spectrograms of Williams and Stevens. Either choice will reveal information about how the acoustic signal of an extreme metal voice, like the speech signals studied by Williams and Stevens, can carry information about the emotion felt (or imitated) by its producer. Further, because extreme metal vocals must draw upon the expressive manipulation of vowel formants rather than the fundamental frequency contour of voiced speech or conventional singing, it seemed plausible to us that F_1 contours in metal screams might be experienced by listeners in comparable ways to F_0 contours in speech and song, much like one can compare F_1 melodies in throat singing to F_0 melodies in other styles.

3.2.2. Resynthesizing the First Vocal Formant

As a way of testing whether the similarities we perceived between Williams and Stevens' spectrograms and those of Lindberg's voice were illusory, we decided to design a band-filter by drawing each frequency's response using Audiosculpt's pencil tool over the top of the vocal signal before increasing the filter's gain levels and processing the treatments created by the pencil tool. The result (shown in the top half of Figure A4) was a new sound file that sounded somewhat like a sine wave, due to its lack of harmonics, but that was recognizably very similar to the original vocal line in terms of its many sudden peaks in amplitude and intensity and its characteristic gradual descent after each vocal phrase (a trait that can be heard amongst black metal singers such as Shagrath of Dimmu Borgir who frequently express a sense of gloom in their lyrics). As a counterexample, we

found that resynthesizing both this vocal line *and* the path of the second formant only made the resulting sound file confusing. What appeared to carry musical-expressive weight was the sudden leaps and peaks of the first formant alone, an acoustic path very much like the prosody that Williams and Stevens discussed, but one created by a lower formant rather than a fundamental frequency contour.

4. CONCLUSIONS

Through the use of spectrograms to generate detailed visual images of extreme metal vocals, as well as by paying special attention to the acoustical characteristics of vowels, this paper has revealed some subtle aspects of extreme metal vocals that have previously passed unnoticed in scholarship on the genre. In addition to demonstrating the central role that vowels play in musical expression as well as the frequency contours of individual formants, this paper has shown how sound spectrograms can be effective tools in drawing attention to these factors, prompting further, especially more systematic, studies into a vastly underexplored field of vocal performance.

5. REFERENCES

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APPENDIX: SPECTROGRAMS

All x- and y-axes are time (sec) and frequency (Hz) respectively.

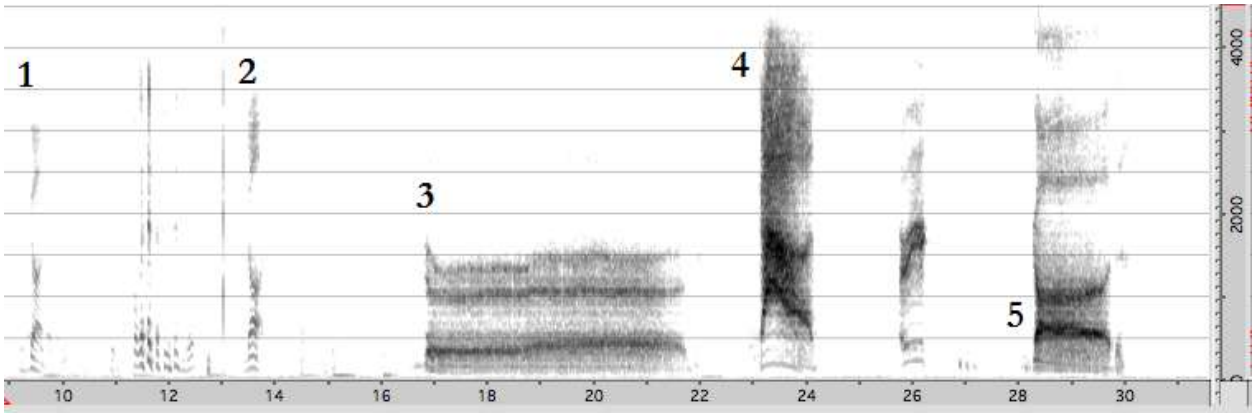


Figure A1a: *Five of the volunteer vocalist's utterances of the word "god." These are numbered 1 through 5 (the spectral image in between numbers 1 and 2 is the vocalist laughing and the spectral image between 4 and 5 is a quick, wordless, inhaled scream often referred to as a "pig squeal").*

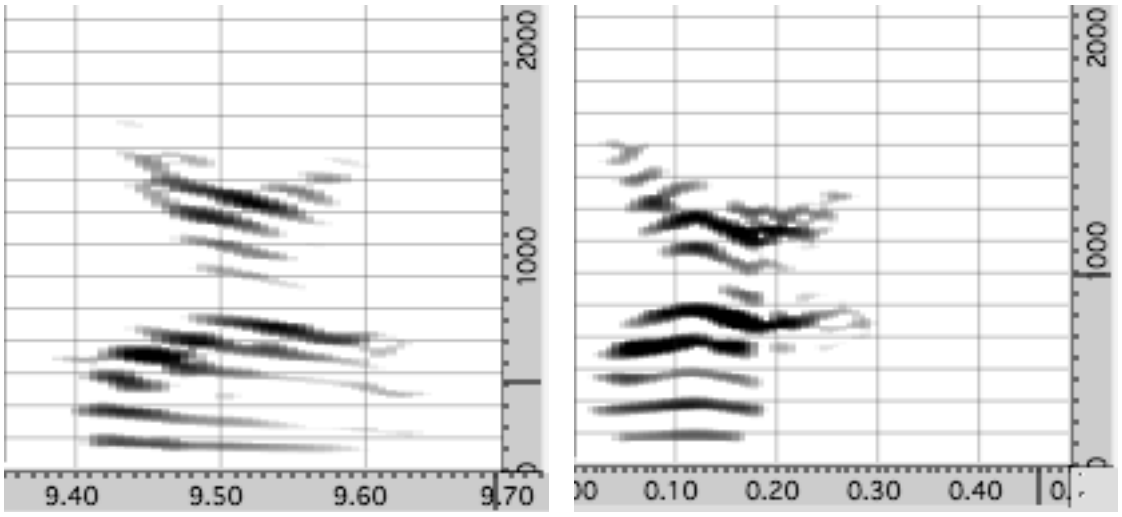


Figure A1b: *A filtered version of Utterances 1 and 2, both examples of the word "God" quickly spoken by the volunteer vocalist. The time axis has been tuned in order to more clearly display the formants and time-frequency regions of the formants have been highlighted by increasing the gain on those points* [7, 8, 9].

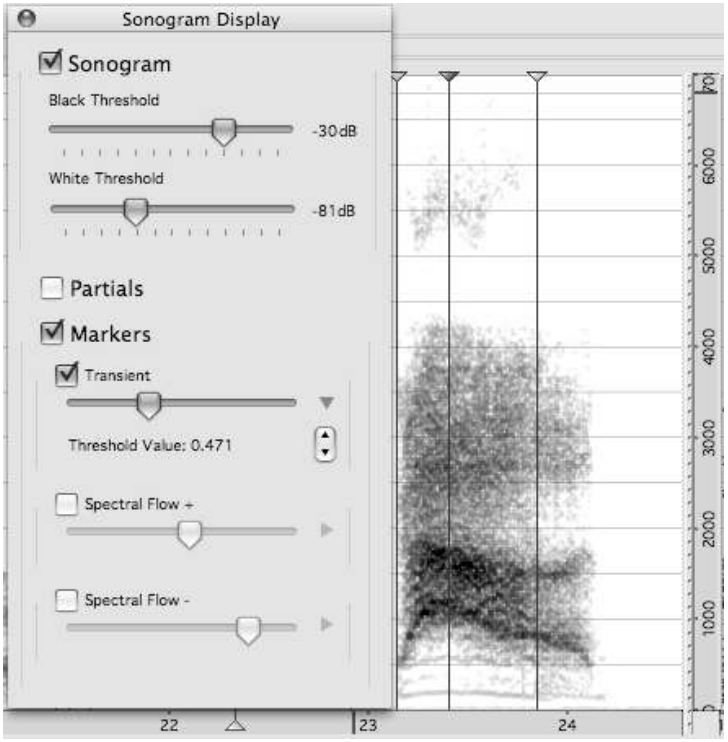


Figure A1c: *Transient markers generated for Utterance 4. The leftmost marker shows the onset of the utterance; the center marker indicates the point of highest first and second formants corresponding to /æ/ ("gad"); the vowel then "descends" to the rightmost marker which shows the onset of /a/ ("god").*

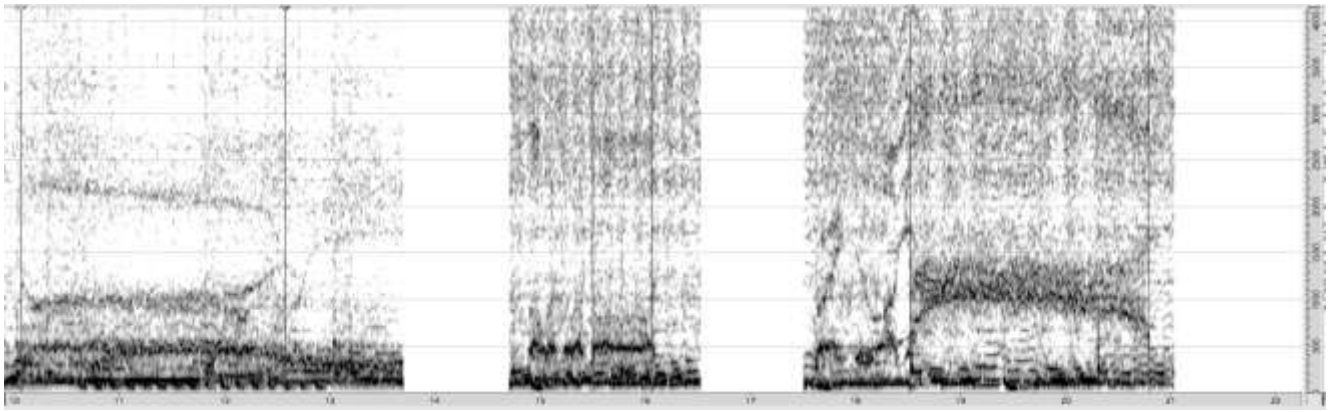
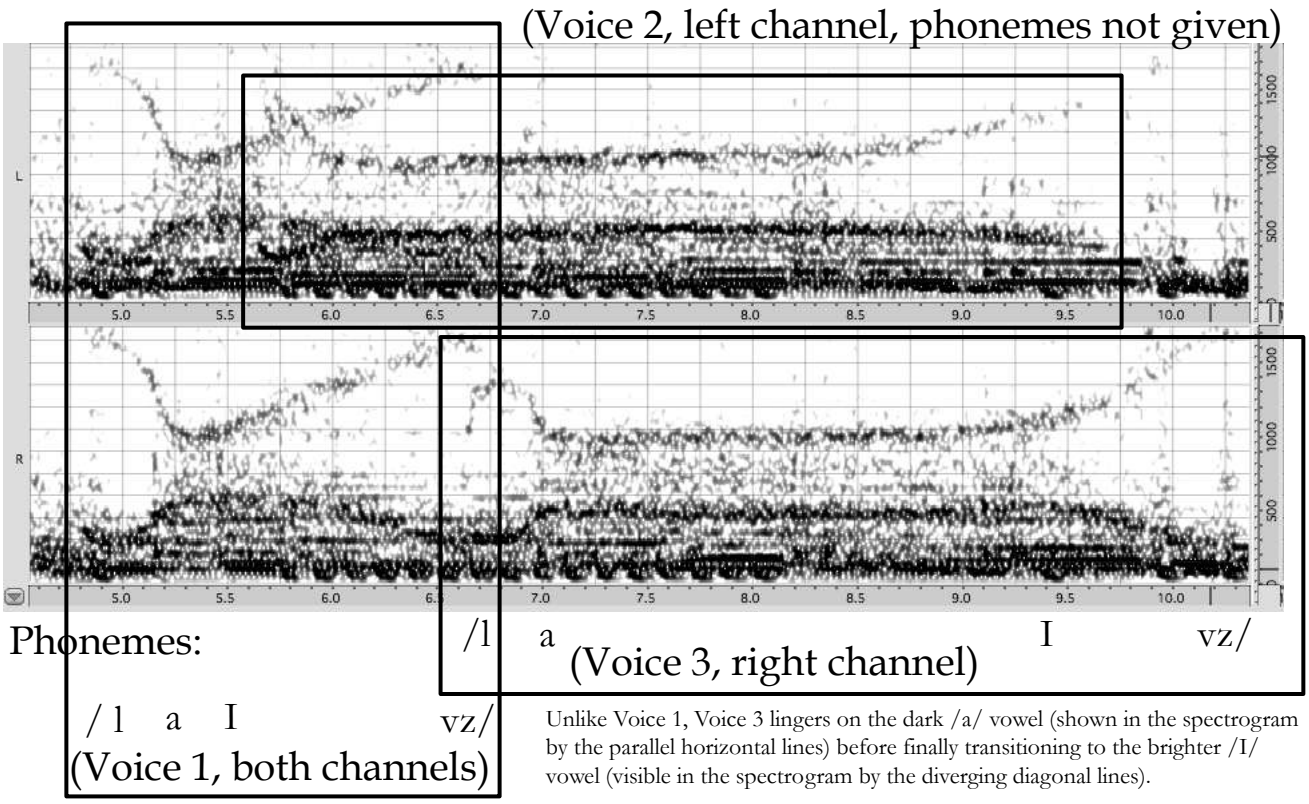


Figure A2: *A comparison of exhale screams on the word "god" by Steve Tucker (sample number 3, far left) and George "Corpsegrinder" Fisher (sample numbers 1 and 2, centre and right images). In each instance, vertical markers indicate the onset and offset of the word "god."*



Unlike Voice 1, Voice 3 lingers on the dark /a/ vowel (shown in the spectrogram by the parallel horizontal lines) before finally transitioning to the brighter /I/ vowel (visible in the spectrogram by the diverging diagonal lines).

Figure A3: *Two spectrograms (left speaker channel on top) showing different transitions through a diphthong in Morbid Angel's "He Who Sleeps" (2:22–2:33).*

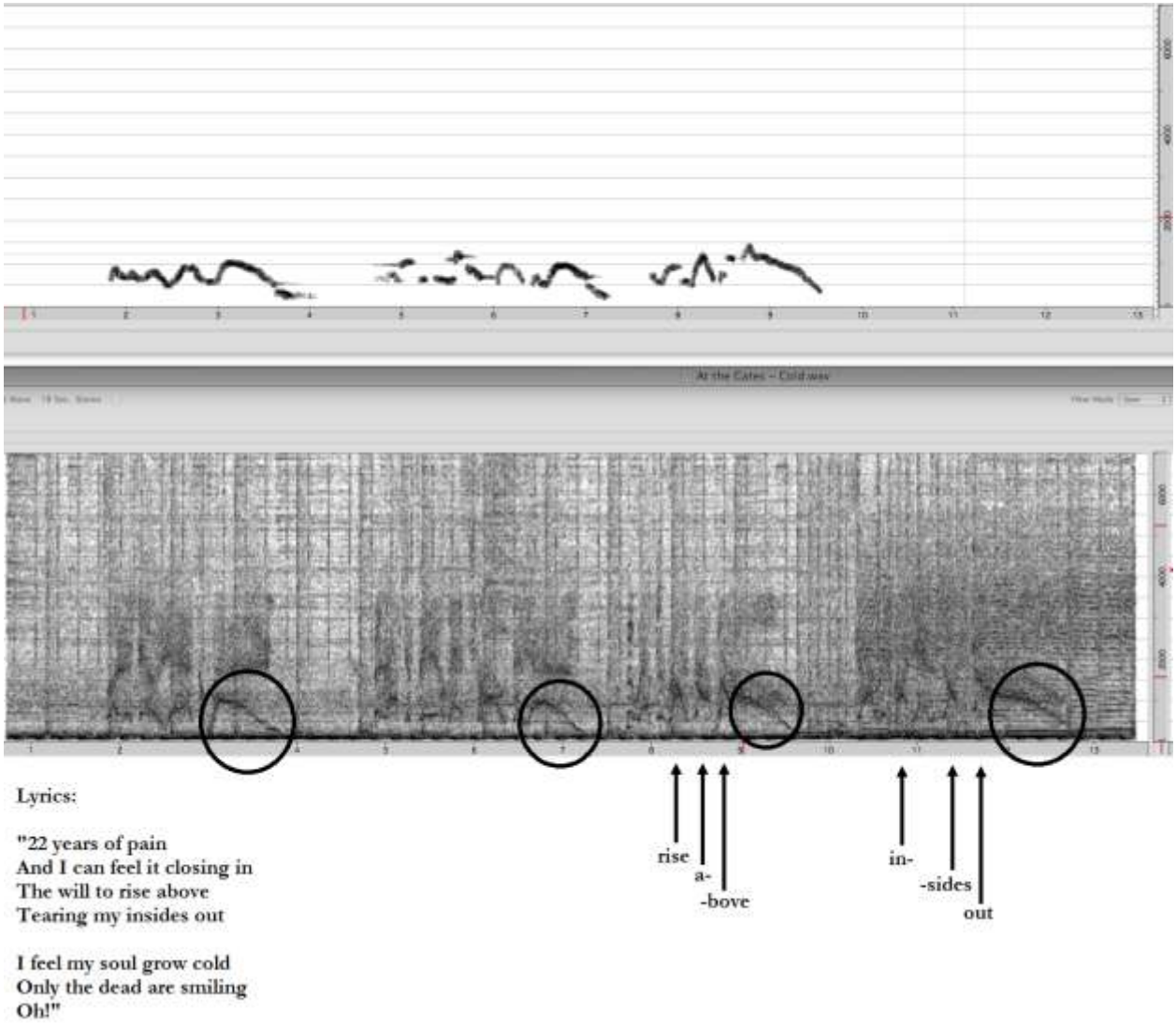


Figure A4: *At the Gates, "Cold" (approx. 2:27–2:40). Our resynthesis of the first formant's path is shown on top and the original spectrogram is shown below. Arrows indicate exceptionally sudden rising and falling motions characteristic of fear. Circles indicate long descents at the ending of phrases.*