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PITCH PROFILE OF THE GLOTTAL WHISTLE (M4)

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ABSTRACT This paper presents a previously unreported method of laryngeal vocal sound production that is capable of producing pitches even higher than the whistle register (M3). Colloquially known as the glottal whistle (here referred to as M4), this method has a wider range than M3 and features frequent instances of biphonation, which is of interest for those involved with contemporary and improvised music. Pitch profile analyses of M4 have found the majority of fundamental frequency (f0) activity to be between 1 and 3 kHz, while the most frequently seen range was between 1000 to 1,500 Hz. Remarkably, multiple singers were able to produce f0 higher than the highest tone on the piano.

(Keywords: glottal whistle, whistle register, M3, voice science, high fundamental frequency)

INTRODUCTION

The singing voice is a remarkable instrument that is capable of presenting enormous emotional depth and expressiveness in a wide variety of contexts. Whether utilizing technical virtuosity or the modesty of a single tone the voice has significant potential to realize diverse classes of sound output.

Extremes of vocal tessitura are numerous that extend from the very low to the very high. In this paper we will focus on a previously unreported method of high pitch singing. Before that, it is worth noting that for the female voice, some methods of high pitched singing include the soprano coloratura which features a fundamental frequency (f0) range from approximately B3 (247 Hz) to A6 (1760 Hz) [1-2]. While, in the upper region of the coloratura range, a phenomenon known as the whistle register (M3) is often used. M3 has in recent years gained more attention by performers of classical, jazz, popular and contemporary music, which has begun to receive increased scientific investigation [3-8]. Sitting higher than the two main laryngeal mechanisms (M1, chest register & M2, head register) M3 typically has a pitch range of approximately 1000 to 2000 Hz, though in exceptional cases it may go much higher [7-10].

An unusual instance of high voice production was first reported in 1902 that described some sort of laryngeal whistle (Spalttöne) that was subsequently referred to in English as a "Chink Tone". This phenomenon ranged from approximately 775 Hz (G5) to 2760 Hz (F7) [8, 11-12], though it is unclear to what exactly the author was referring to in his paper.

High pitched male singing includes the classical tenor voice which ranges from approximately A#2 (116 Hz) to F5 (698 Hz) [13], while the male falsetto ranges from approximately A3 (220 Hz) to G5 (784 Hz) [14]. The yodel which occurs in a variety of western and nonwestern (ethnic, folk and popular) music often features registral oscillation from modal to falsetto mostly at an octave in the male voice [15]. Utilizing a naturally high male soprano or falsetto, the countertenor voice encompasses a range from approximately G3 (196 Hz) to G5 (784 Hz) [16]. A different type of high pitched male singing features not only the range but also the quality of the female voice. Males with this disorder, known as the Kallmann Syndrome that occur as the result of a genetic disorder characterized by a failure to complete puberty or a decreased function of the glands that produce sex hormones (hypogonadism), have a voice quality similar to that of women. The condition has a low prevalence, and is estimated at 1:10,000 males. The best-known singer with the Kallmann syndrome is the jazz vocalist Jimmy Scott who has a range of approximately C3 to F5 [17-21]. In a completely different way, the Castrato was a high male voice whose physiology was, by today's standards, cruelly and artificially altered to produce a voice quality and range aligned with the soprano [22]. In 1904 the last castrato Alessandro Moreschi was

recorded in the Sistine Chapel in the Vatican [23]. In his recording of "Hostias Et Preces" by Eugenio Terziani (1824-1889) [24], the pitch profile reveals the highest pitch at 800 Hz (G#5). It was reported that the legendary Farinelli had a voice spanning over three octaves, from C3 (131 Hz) to D6 (1175 Hz) [25] **(Table 1)**.

Table 1. Listing of high pitched oscillatory behaviors with approximate ranges

Pitch range profile of high oscillatory voiced behaviors		
Soprano coloratura	B3 to A6	247 Hz to 1760 Hz
Whistle register (M3)	B5 to C7	1000 Hz to 2000 Hz
Spalttöne ("Chink")	G5 to F7	775 Hz To 2760 Hz
Tenor voice	A#2 to F5	116 Hz to 698 Hz
Male falsetto	A3 to G5	220 Hz to 784 Hz
Yodel	Chest to mid, mid to head	Varies
Countertenor	G3 to G5	196 Hz to 784 Hz
Kallmann Syndrome	C3 to F5	130 Hz to 700 Hz
Castrati	C3 to D6	131 Hz to 1175 Hz

However, there is another form of laryngeally produced voice that sits in an even higher range which is known as the glottal whistle (in this study referred to as M4) [26]. This type of production is seen in contemporary and free-improvised music with instances reported in non-artistic domains, such as during children's play, childbirth and perhaps in animal vocalization, but in human singing has received no reported scientific investigation [27].

While singing in M4 it may not be possible to control pitch with any precision, nor in many cases whether it is monophonic or multiphonic. Therefore it is relevant to consider whether M4 is best considered a register or some other category of unusual vocal behavior. However, like the often reported vocal registers M1, M2 and M3 it is possible to transition into and out of M4 from chest, mid or head registers. For normal oscillatory singing these regions of transition have been identified as follows: the *primo passaggio* from M1 to M2 has been reported to occur around E4-F4 (~340 Hz) [7, 10, 14, 28]. A second transitional area, the *secondo passaggio* occurs in the region of C5 to G5 (~500 – 700 Hz), which some have suggested more appropriately divides the female head register into middle and upper tessitura [14, 28-30]. A third, larger region has been reported higher in the soprano voice, corresponding approximately to E5 – G6. When a soprano is able to sing in the whistle register, a transition between M2 and M3 will likely occur above E5 [3-5, 8, 10, 31-35].

METHODS

This study analysed 41 voice samples from eight singers producing M4 and two excerpts from two singers producing M3. We chose the samples based upon perceptual evaluation suggesting episodes featuring clear instances of M4 (or M3 in two cases). These excerpts were digitally extracted from publicly available CD recordings and private & rehearsal recordings by author MEE.

All samples used recordings from solo singers that were mostly unaccompanied (the exception being the recording of Erna Sack from 1936 *Una voce poco fa* from *il barbiere di Siviglia*) [36, 37]. For M3 the singers on the recorded samples included Erna Sack (the German Nightingale) an opera singer, and Adam Lopez a pop musician from Australia. For M4, the singers all had a career or interest in contemporary classical music and/or jazz to free improvisation. These singers included: Jaap Blonk, Anna Homler, Almut Kuehne, Juergen Neubauer, Amy Stebbins, Demetrio Stratos, Rebekka Uhlig and Angela Rademacher née Wingerath [38-46].

The recordings utilized no processing of any kind, neither dynamically (dynamic compression or enhancement) nor spectrally (filtering, pitch shifting, chorusing, phasing). The samples were recorded at a sampling rate of 44100 Hz with a resolution of 16 bits/sample. The window length was set to 30 ms (0.03 seconds) which produced a narrow band spectrogram with a bandwidth of 43 Hz. Each frame used the part of the sound that lay between 0.015 seconds before and after the centre of that frame.

RESULTS

Pitch and range

M4 exists in a high range. In comparison, the fundamental frequency (f0) of the whistle register (M3) typically ranges from

approximately B5 (990 Hz) to A6 (1760 Hz) [7-10]. **Figure 1** shows an example of the German nightingale (Die Deutsche Nachtigall) Erna Sack from a recording in 1936 while singing "Una voce poco fa" from Il barbiere di Siviglia by Gioacchino Rossini who switches from head to whistle register. However, sometimes the f0 of M3 may go much higher. **Figure 2** shows a spectrogram made from a televised broadcast recording from 2005 at the Channel 7 studios in Australia, in which the pop singer Adam Lopez [47], who had already publicly sung a D7, extended the highest sung note (oscillatory mode) to a C#8 (4435 Hz) and thus setting a new Guinness World Record.

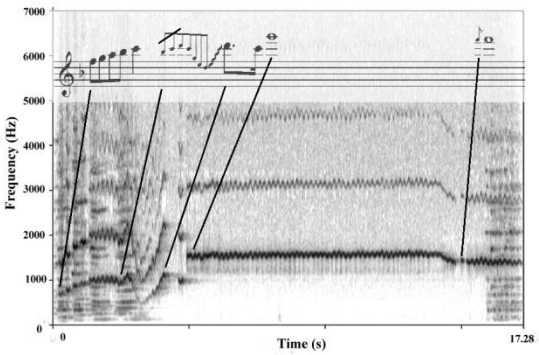


Figure 1. Erna Sack (1936); "Una voce poco fa" from Il barbiere di Siviglia, 1816 by Gioacchino Rossini with a lengthy sustained tone on G6 in M3 register – this excerpt features both the head (M2) and whistle registers (M3) (Rossini, 1936).

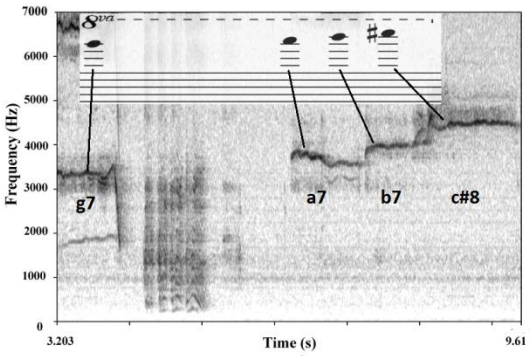


Figure 2. Adam Lopez producing the tone C#8 (4565 Hz) at the end of a 4 note sequence (G7 - A7-B7-C#8) (Lopez, 2005).

M4 typically has a range from approximately 1000 to 2500 Hz, though the f0 may go much higher. **Figure 3** shows an excerpt of singing in M4 with a pitch range from approximately 1 to 2.5 kHz that was sung by Anna Homler [39] in her improvisation titled *Signals*. In 1978 Demetrio Stratos released an album titled *Cantare la voce* [43] which featured an improvisation titled *Passaggi*.

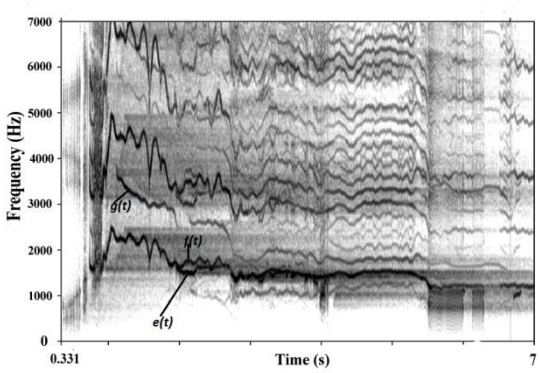


Figure 3. Glottal whistle (M4) by Anna Homler in "Signals" featuring biphonic and monophonic instances. The f0 ranges approximately between 1 and 2.5 kHz (Homler, 1989).

Figure 4 shows a spectrogram of an excerpt from this performance in which Stratos produced a very high glottal whistle whose peak at 6503 Hz was nearly 2000 Hz above the highest point in fig 2 (or a perfect fifth above – G#8) and constitutes the highest laryngeally produced fundamental frequency reported.

M4 features an unusual timbral quality that resembles a whistle produced deep in the throat. Significantly, M4 features harmonic content that ranges from full, rich tones to those closer to a sine wave. For an example of richer, fuller tones note how **figure 3** features many harmonics as well as combination tones that contribute to the relativeness richness of timbre.

The lowest pitches for the majority of M4 samples were near 1 kHz while the highest pitches were generally lower than 4 kHz. **Figure 5** shows an instance of singing in M4 below 1 kHz, at the marked instance the f0 is approximately 750 Hz (F#5).

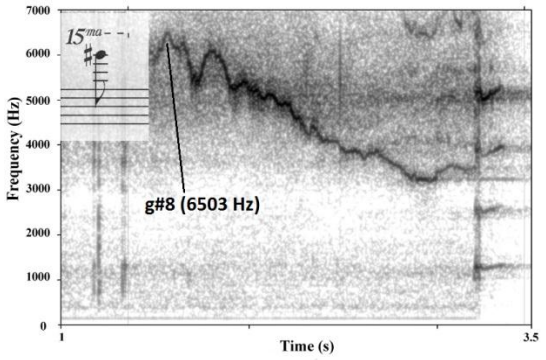


Figure 3. *Passagi* by Demetrio Stratos producing a very high glottal whistle (M4) – at the cursor the whistle follows a preparatory phase with its highest peak at 6503 Hz, approximately a G#8, or a P5 above the peak in fig. 2! (Stratos, 1978).

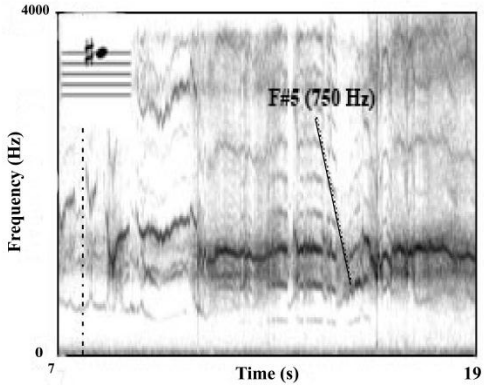


Figure 4. *Anaphora* by Michael Edward Edgerton and sung by Rebekka Uhlig who produces a very low M4 tone. Generally M4 pitches are above 1 kHz, however in this sequence the f0 is near 750 Hz (F#5).

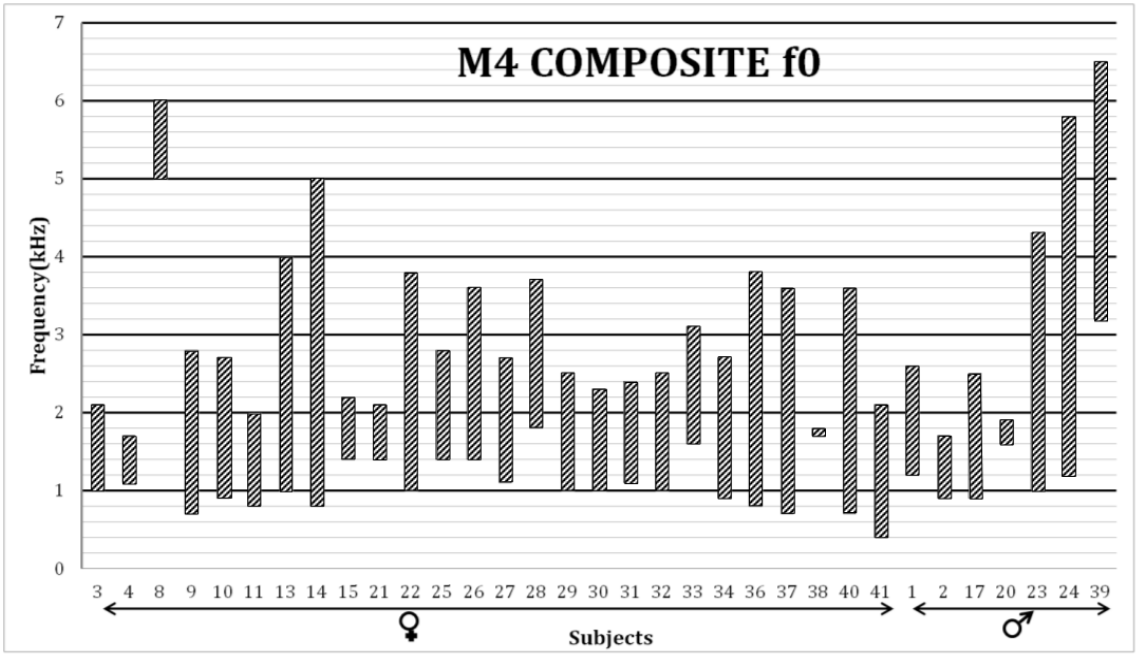


Figure 5. Pitch (fundamental frequency) range profile for 33 samples

Figure 6 shows the composite ranges for 35 different M4 samples. In this pitch profile the majority of activity lay between 1 and 3 kHz. The gender distribution of these samples consisted of 26 women, 7 men. Surprisingly the highest f0 was produced by a male while the lowest f0 was produced by a female. No claim is made here favouring one gender over the other regarding proficiency, ability, likelihood, nor ease of M4 production.

Remarkably, the widest M4 range featured an extent of 4.6 kHz, while the narrowest range consisted of a nearly stable tone with a 100 Hz deviation over time. **Figure 7** shows that the M4 range that occurred most often was 1.1 to 1.5 kHz at 28% of the time, while the ranges .6 to 1 kHz and 2.6 to 3 kHz each occurred 17% of the time. Next, **figure 8** reveals that exactly one-half of the samples featured a lower threshold at 1 kHz (+/- 200 Hz), while another 33% were at 1.5 kHz. Interestingly, the upper threshold for M4 featured a more uniform distribution, occurring at 2.5 kHz - 25%, 2 kHz - 19%, 3.5 kHz - 14%.

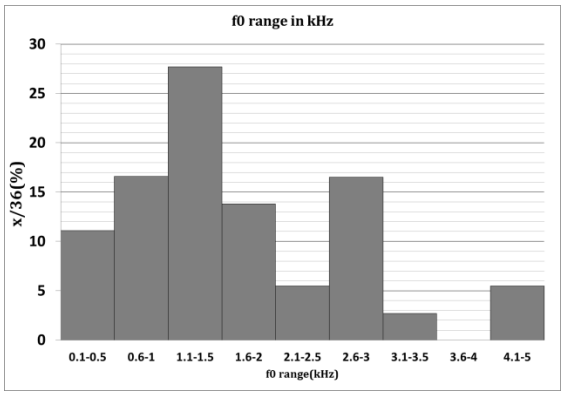


Figure 6. A pitch range of 1-1.5 kHz was seen most often in M4

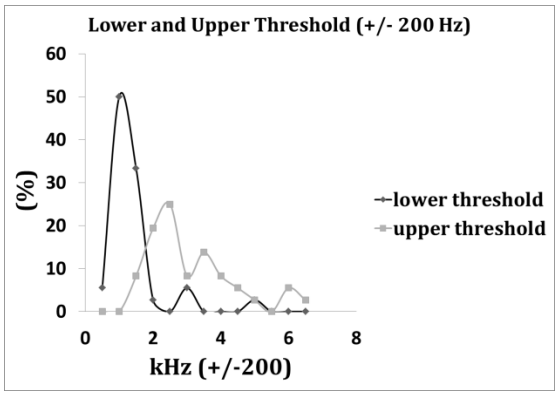


Figure 7. 50% of M4 featured low pitches at 1 kHz while upper pitches occurred most often at 2.5 kHz

Table 2. composite ranges itemized by gender, with musical notation and its placement on keyboard

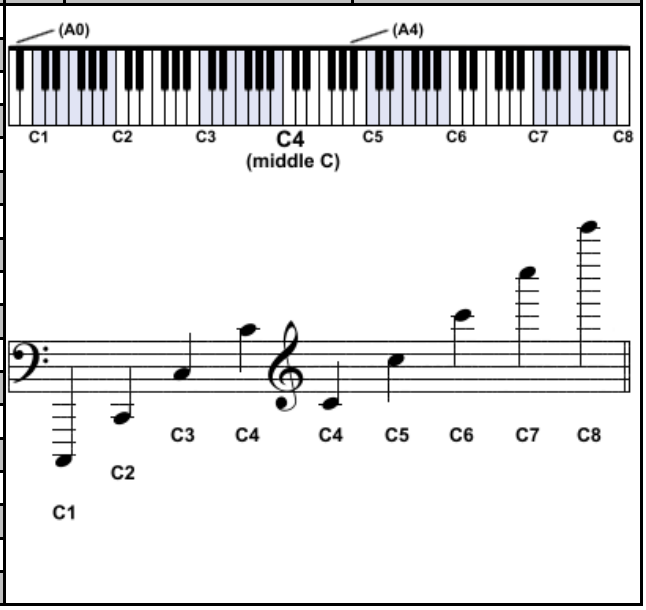
Composite Range					
♀			♂		
03	1 – 2.1 kHz	B5 – C7	**01**	1.2 – 2.6 kHz	D6 – E7
04	1.1 – 1.7 kHz	C#6 – G#6	**02**	0.9 – 1.7 kHz	A5 – G#6
08	5.0 – 6.0 kHz	D#8 – F#8	**17**	0.9 – 2.5 kHz	A5 – D#7
09	0.7 – 2.8 kHz	F5 – F7	**20**	1.6 – 1.9 kHz	G6 – A#6
10	0.9 – 2.7 kHz	A5 – E7	**23**	1.0 – 4.3 kHz	B5 – C8
11	0.8 – 2.0 kHz	G5 – B6	**24**	1.2 – 5.8 kHz	D6 – F#8
13	1.0 – 4.0 kHz	B5 – B7	**39**	3.2 – 6.5 kHz	G7 – G#8
14	0.8 – 5.0 kHz	G5 – D#8			
15	1.4 – 2.2 kHz	F6 – C#7			
21	1.4 – 2.1 kHz	F6 – C7			
22	1.0 – 3.8 kHz	B5 – A#7			
25	1.4 – 2.8 kHz	F6 – F7			
26	1.4 – 3.6 kHz	F6 – A7			
27	1.1 – 2.7 kHz	C#6 – E7			
28	1.8 – 3.7 kHz	A6 – A#7			
29	1.0 – 2.5 kHz	B5 – D#7			
30	1.0 – 2.3 kHz	B5 – C#7			
31	1.1 – 2.4 kHz	C#6 – D7			
32	1.0 – 2.5 kHz	B5 – D#7			
33	1.6 – 3.1 kHz	G6 – G7			
34	0.9 – 2.7 kHz	A5 – E7			
36	0.8 – 3.8 kHz	G5 – A#7			
37	0.7 – 3.6 kHz	F5 – A7			
38	1.7 – 1.8 kHz	G#6 – A-6			
40	0.7 – 3.6 kHz	F5 – A7			
41	0.4 – 2.1 kHz	G4 – C7			

Table 2 offers another view of the composite ranges for each singer, itemized according to gender that additionally pairs musical notation with its visual placement on the piano keyboard. It may be worth noting that samples # 08, 14, 24, and 39 feature upper pitch thresholds higher than the highest note on the piano.

DISCUSSION

Singing at high pitches has for a very long time occupied a unique role in classical, popular, world and experimental performance [26, 36, 48, 49]. In the literature M3 is considered to occupy the highest known register of laryngeally produced sound [7, 10]. However, this paper provides evidence that there is one method utilizing laryngeally produced sound that features an even higher tessitura, known here as M4.

The practical experience of author MEE as composer, pedagogue and performer often involved with M4 production has revealed that it may not be possible to control exact pitch with any precision. Therefore, although this form of sound production is produced laryngeally, we must question whether it is best considered as a register. Two arguments for considering M4 as register are: 1) the numerous instances of transitions into and out of M4 from M1/M2/M3/asymmetry, and; 2) the ability to combine M4 with another mode, which is already known in the case of [imitated Tibetan] Chant which for some subjects combines M1 with M0 (here meaning vocal fry) [26, 27, 50].

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