Positive Effect of Noise On Self-Perceived Vocal Control

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Good vocal control discriminates between the trained and untrained voice and critically contributes to the quality of singing. Achieving such high vocal control capabilities presents considerable challenges for professional Western singers, especially at the high tessitura of their vocal range. While training and teaching classical singing, one of the authors (T.M.) found a positive effect of running-water noise on vocal control. The effect was strongest in the more challenging aspects of singing. The purpose of the present study was therefore to examine this effect in a controlled experiment. In the initial phase described here, we set out to determine the effect of background noise on singers' perception of their own vocal control. Eleven soprano singers (students and professionals) performed 5 musical excerpts twice consecutively, with or without noise (administered through headphones). They were then asked to evaluate their performance according to nine criteria assessing key skills of vocal control. Statistical analysis showed that the noise condition was significantly preferred for the majority of the assessed criteria: "feeling comfortable about my singing" (p<0.001), "ease of singing high notes in terms of vocal effort" (p<0.001), "better ability to sing longer sustained notes" (p<0.001), "feeling that my singing was more correct" (p=0.002), "flexibility of voice in transition between notes" (p=0.016), "better vocal control" (p=0.016). In future stages of this study, the recorded excerpts will be analyzed acoustically and in addition these excerpts will be presented to experts for evaluation, in order to determine if the described effect is also perceptually discernible.

1 Introduction

Many years of study with a vocal training teacher and daily exercises are what eventually lead to the greatest possible vocal control – this is more or less the answer given by every professional singer or vocal training teacher to the question of how to achieve good vocal control.

Vocal control in general often serves as a definition for the act of singing itself, and is one of the major differences between speaking and singing voices [1]. Learning vocal control, in the context of learning to sing, includes establishment of several "new patterns for breathing, articulation, and phonation" [2]. These new patterns provide the singer with the ability to perform the largest possible number of qualitative changes in his voice, in any intensity or pitch, for musical expression. These patterns enable independent control of all vocal characteristics, as opposed to speech, in which, for example, the intensity rises together with the pitch [2-4]. We can discriminate between an experienced and inexperienced voice by the level of vocal control [3,5].

A classical singer learns to control his voice just like a musician learns to play an instrument, with the goal of reaching the best possible skill level required for performing musical compositions. The skills required include the ability for smooth transitions between notes throughout a wide vocal range, with different tempi, dynamics, and articulation. In addition, the singer must be able to make himself clearly audible in large halls even with an accompaniment (orchestral, choral, and others), alongside the ability to sing for long periods of time without tiring. Several important criteria characterize good vocal control:

- The ability to sing without overstraining the voice [2,6] or without "pushing" or "stretching" [7]. Strained or pushed singing is characterized by pressed phonation [6,8] and may harm the voice. Instead of a sense of overstrain, there should be a sense of easiness or comfort in the muscles involved in vocal production [7].[1]

- High vocal flexibility or high vocal coordination, characterized by the ability to transition smoothly between notes of different pitch and duration throughout the vocal range, with different dynamic nuances, articulation (e.g. legato, staccato), and tempi [2,5]. This ability to make a smooth transition between the notes despite the changes in the various sound parameters is vital for the creation of good musical phrasing [9].

- Amplification ability or "carrying power" [6,10] or "resonance" [11].

It is possible to identify or estimate good vocal control more clearly in various challenging conditions or situations, which are well known in Western classical music such as high tessitura; singing a sustained note within the required dynamic range (particularly in *piano*, and especially in a high tessitura); singing a sustained phrase in a slow tempo, while maintaining legato[2], and fast-paced singing (vocal agility) [1,3,5,6,7,12,13].

While pursuing a professional career in performing and teaching classical singing, one of the authors (T.M.), discovered that practicing singing in the presence of certain types of background noise (notably the sound of running water) had an interesting effect on vocal control ability. T.M. noted that background noise seemed to improve vocal control, both from the point of view of the singers themselves, and also in terms of the quality of the vocal production as perceived by listeners. The improvement was in vocal control in general, particularly in the more challenging singing conditions. The presence of background noise seemingly helped with: (a) rising to high climax notes and the ability to sustain them in *forte* and *piano* dynamics; (b) the ability to achieve a smooth transition between the notes (legato) in slow tempo; (c) singing longer legato phrases; (d) achieving vocal agility when the tempo was brisk. A clearer improvement was observed in the higher part of the basic vocal range, suited to the singer's specific voice type, or the specific range of a particular singer.

To examine the phenomenon empirically, a study was therefore designed comprising three complementary parts:

- Singers self-rating of their subjective feeling with regard to their own vocal production while singing with and without background noise.

[1] This is a feeling of comfort in the upper areas of the system involved with voice production – the mouth, and larynx and pharynx muscles.

[2] A smooth transition between the notes, "connected" notes.

- Expert (singing pedagogues) evaluation of the recorded singing sessions of the singers in the first stage using criteria related to vocal control.

- Acoustic analysis of the singers' recordings.

This paper describes only the first stage of the study. The justification for this stage is based on previous studies that have shown that singers demonstrate consistency and reliability when reporting feelings of unease and difficulty connected with vocal production and control [1]. Similar consistency was also reported for the subjective perception of good singing connected with a particular type of production – the open throat technique [12]. Moreover, the problems of production connected with vocal instability or reduced control can be so delicate that they are noticed only by the singer, without being visible in acoustic measures, and without arousing the attention of the listener [1].

Therefore, for the first stage of our study, the singers were asked to evaluate their singing from their own subjective perspective, with and without accompanying background noise.

2 Method

2.1 Participants

Eleven soprano singers, students or graduates of institutions of higher education in the field of Western classical singing, aged 19-41 (Mean=27, SD=6.08) participated in the first part of the study. Participants received professional vocal training for 2 to 18 years, (Mean= 8, SD=5.31)

2.2 Musical Materials

Five musical exercises were selected, presenting various challenging requirements of classical singing and included selected pieces from arias, as well as arpeggio exercises, which are similar to the usual warm-up exercises. The pieces were judged by the experimenters to be within the participants' singing ability.

Exercises 1 and 2 included bars 34-36 from Handel's aria, "*Ombra mai fu"*. In both exercises, the singers were asked to sustain the highest pitch (F5) with a fermata sign above it, for as long as they were able. In Exercise 1 they were asked to sing the sustained note in *forte*, and in Exercise 2 – in *piano.*

These exercises illustrate the combination of several performance demands including legato singing with sustained phrasing in a slow tempo, high tessitura, and high-sustained pitch, at the climax of the musical phrase.

Exercise 3 comprised of bars 23-28 from Parisotti's aria *Se tu m'ami* written as a simple Italian song, in high tessitura, which calls for a smooth transition between pitches and agile tempo. The singers sang the exercise on the g- minor scale at a tempo of 120 beats per minute.

Exercises 4 and 5 included a rising and falling arpeggio similar to a regular warm-up exercise beginning with the notes E4, G# 4, B4, E5, B, G#, E (falling), and was sung with the syllables *mi-hi-hi-ya-ha-ha-ha*. For the syllable, *ya* (E5), the singers were asked to sustain the note for as long as they could. The arpeggio pattern repeated sequentially, with each repetition rising by a semitone up to the arpeggio, which begins with G4. Like Exercises 1 and 2, the musical material in Exercises 4 and 5 was identical; apart from a difference in the dynamics of the sustained high pitch (the octave from the pitch from which they began). In Exercise 4, the singers were asked to sing that high pitch in *forte*, and in Exercise 5 – in *piano*. In this way, both these exercises illustrate a condition of singing with a broad dynamic range, at a high tessitura, with a sustained high pitch.

The background noise used for the experiment was that of running water from a showerhead onto a water-filled bath. It was pre-recorded in stereo in a bathroom, using a Zoom H4 recorder. The equivalent continuous sound level of the noise as played to the participants through the earphones was 57dB. This was measured using a Verifit Real Ear Measurement system

2.3 Procedure

The singers were asked to sing the each exercise with and without background noise. To avoid bias, they were told that noise was present throughout, but sometimes at inaudible levels. They were asked to keep the earphones on in the same way for the entire time they sung to ensure equal singing conditions. Each exercise was carried out once with background noise and once without, with two such consecutive renditions defined as a "set" (e.g., exercise 1 without noise followed by that same exercise with noise). Each set was performed twice in a reverse internal order (e.g., if the first set comprised of exercise 1 without noise followed by that same exercise with noise then set 2 comprised of exercise 1 with noise followed by that same exercise without noise).

The noise was played to the singers through Apple Ear Pods, which are non-close-fitting earphones. Thus, when there was no background noise, they heard themselves in a way that was very close to normal, even when keeping the earphones on.

After singing each set of exercises, they were asked to compare the two singing trials in that set along nine criteria using a Likert scale (1-7). This scale comprised of 7 equally spaced points along a continuum. On one extreme was noted "no noise" and on the other "with noise". If, for example, the criterion was "better vocal control" and participants felt this was clearly better under no noise condition, they marked the most extreme point in that direction. If, however they felt there was no significant difference between the conditions they could mark the point at the middle of the scale, and so forth. The nine chosen criteria are known to characterize good vocal control, some of which were previously observed by T.M. to be affected by noise. The 9 criteria were as follows:

- I heard myself better
- Better ability to sing longer sustained notes
- Ease of singing high notes in terms of vocal effort
- My singing feels more beautiful
- Flexibility of voice in transition between notes
- Feeling comfortable about my singing
- Feeling that my singing was more correct
- Better vocal control
- Accuracy of intonation in singing

In sum, each participant sang each exercise four times and filled in questionnaires twice each time, after completing each set for a total of 990 measurements (11 participants × 5 exercises × 2 sets × 9 criteria). The singing was recorded for later analysis; however, these recordings are not dealt with in this paper.

2.4 Results

For the analysis, we first translated the 7-point scale (1-7) into a -3 to +3 scale with a mean of 0. Since we have two orderings of sets (noise first/noise second) and five different pieces with two pairs of excerpts (exercises 1 and 2 "*Ombra mai fu*" and exercises 4 and 5 - rising and falling *Arpeggio*) performed twice, with differing dynamics (*forte* vs. *piano*) we first tested whether these variables have any effects on the ratings of the nine criteria.

As seen in Tables 1 and 2, there were no such significant effects (except for the borderline result of p=0.025[3] for the influence of the specific piece on criterion 9). We therefore included in the following analyses all the data across the two sets and the five pieces[4]

Table 1: The Influence of Set Order on Ratings of the 9 Criteria

Set Order	N	Mean Rank	Sum of Ranks	Wilcoxon Exact Sig.(1-tailed)	Mean
1. The ability to better hear myself					
With→ Without	55	54.60	3003.00	0.30	-1.18
Without→With	55	56.40	3102.00		-1.04
Total	110				-1.11
2. Better ability to sing longer sustained notes					
With→ Without	55	59.79	3288.50	0.14	.84
Without→With	55	51.21	2816.50		.42
Total	110				.63
3. Easiness of singing high notes in terms of voice effort					
With→ Without	55	59.84	3291.00	0.23	1.15
Without→With	55	51.16	2814.00		.67
Total	110				.91
4. My singing feels more beautiful					
With→ Without	55	58.60	3223.00	0.30	.89
Without→With	55	52.40	2882.00		.49
Total	110				
5. Flexibility of voice in transition between notes					
With→ Without	55	59.75	3286.50	0.18	.75
Without→With	55	51.25	2818.50		.22
Total	110				.48
6. Feel comfortable about my singing					
With→ Without	55	58.20	3201.00	0.38	1.05
Without→With	55	52.80	2904.00		.69
Total	110				.87
7. Feel more correct about my singing					
With→ Without	55	60.43	3323.50	0.12	.96
Without→With	55	50.57	2781.50		.36
Total	110				.66
8. Better voice control					
With→ Without	55	59.36	3265.00	0.12	.65
Without→With	55	51.64	2840.00		.22
Total	110				.44
9. Accuracy of intonation in singing					
With→ Without	55	60.87	3348.00	0.08	.51
Without→With	55	50.13	2757.00		-.16
Total	110				.17

Table 2: The Influence of Dynamics (Forte vs. Piano) and Specific Exercise (1 & 2 vs. 4 & 5) on Ratings of the 9 Criteria

Variable	N	Mean Rank	Sum of Ranks	Wilcoxon Exact Sig. (1-tailed)
1. The ability to better hear myself				
1,4 Forte	44	44.34	1951	0.475
2,5 Piano	44	44.66	1965	
Exercise 1,2	44	44.61	1963	0.485
Exercise 4,5	44	44.39	1953	
2. Better ability to sing longer sustained notes				
1,4 Forte	44	44	1936	0.425
2,5 Piano	44	45	1980	
Exercise 1,2	44	41.86	1842	0.165
Exercise 4,5	44	47.14	2074	
3. Easiness of singing high notes in terms of voice effort				
1,4 Forte	44	46.91	2074	0.185
2,5 Piano	44	46.91	1852	
Exercise 1,2	44	46.91	1825.5	0.185
Exercise 4,5	44	47.51	2090.5	
4. My singing feels more beautiful				
1,4 Forte	44	47.51	2005	0.345
2,5 Piano	44	47.51	1911	
Exercise 1,2	44	44.05	1911	0.345
Exercise 4,5	44	44.95	1978	
5. Flexibility of voice in transition between notes				
1,4 Forte	44	44.95	1890	0.285
2,5 Piano	44	44.95	2026	
Exercise 1,2	44	44.97	1978.5	0.430
Exercise 4,5	44	44.03	1937.5	
6. Feel comfortable about my singing				
1,4 Forte	44	44.58	1961.5	0.490
2,5 Piano	44	44.42	1954.5	
Exercise 1,2	44	43.4	1954.5	0.340
Exercise 4,5	44	45.6	2006.5	
7. Feel more correct about my singing				
1,4 Forte	44	45.6	1934	0.340
2,5 Piano	44	45.05	1982	
Exercise 1,2	44	47.36	2084	0.145
Exercise 4,5	44	41.64	1832	
8. Better voice control				
1,4 Forte	44	42.89	1887	0.275
2,5 Piano	44	46.11	2029	
Exercise 1,2	44	46.11	1904	0.325
Exercise 4,5	44	45.73	2012	
9. Accuracy of intonation in singing				
1,4 Forte	44	44.11	1941	0.445
2,5 Piano	44	44.89	1975	
Exercise 1,2	44	39.15	1722.5	0.025
Exercise 4,5	44	49.85	2193.5	

In order to check whether the ratings confirmed positive influence of background noise in singing as measured in our 9 criteria, we first generated a "control" sample of normally distributed data with no preference between conditions (mean=0, on the converted -3 up to 3 scale). We then used Exact Sig. (1-tailed) Wilcoxon test to compare our data with this "control" sample (referred to as the "control Group" in Table 3 and in the following text).

As seen in Table 3, the ratings were significantly higher in the vast majority of the assessed criteria: "feel comfortable about my singing" (p<0.001), "easiness of singing high notes in terms of voice effort" (p<0.001), "better ability to sing longer sustained notes" (p<0.001), "feel more correct about my singing" (p=0.002), "flexibility of voice in transition between notes" (p=0.016), "better voice control" (p=0.016), "my singing feels more beautiful"(p<0,001). For "the ability to better hear myself" participants preferred the absence of noise (p<0.001) and for "intonation in singing" they showed no preference (p=0.176).

[3] Given that we used a number of criteria which were found to be in high correlation we opted for a more conservative value of α= 0.025 .

[4] We also tested the influence of exercise 3 and it was found to have no significant influence.

Table 3: Wilcoxon Test for the Rating of the 9 Criteria Under Noise Condition ("Research Group") as compared to the Control "No Preference" Group

Group	N	Mean Rank	Sum of Ranks	Wilcoxon Exact Sig. (1-tailed)
1. The ability to better hear myself (Reversed)				
Control	110	88.08	9689	0.000
Research	110	**132.92**	14622	
Total	220			
2. Better ability to sing longer sustained notes				
Control	110	**122.79**	13507	0.002
Research	110	98.21	10803	
Total	220			
3. Easiness of singing high notes in terms of voice effort				
Control	110	**128.34**	14118	0.000
Research	110	92.66	10193	
Total	220			
4. My singing feels more beautiful				
Control	110	**123.90**	13630	0.001
Research	110	97.10	10681	
Total	220			
5. Flexibility of voice in transition between notes				
Control	110	**119.55**	13151	0.016
Research	110	101.45	11160	
Total	220			
6. Feel comfortable about my singing				
Control	110	**127.47**	14022	0.000
Research	110	93.53	10288	
Total	220			
7. Feel more correct about my singing				
Control	110	**122.96**	13526	0.002
Research	110	98.04	10784	
Total	220			
8. Better voice control				
Control	110	**119.60**	13157	0.016
Research	110	101.40	11154	
Total	220			
9. Accuracy of intonation in singing				
Control	110	114.45	12590	0.176
Research	110	106.55	11721	
Total	220			

Since in 7 of the 9 criteria (2-8) the noise condition received higher ratings we checked to see whether these criteria were inter-correlated. Spearman Correlation shows that there is a high intercorrelation ($0.180< r <0.814$, $0.030< p<0.0001$) suggesting that these criteria should be clustered into a single factor referred to in the following as the "new scale of vocal control".

In the next stage, we examined the internal consistency of our new scale for vocal control using the Cronbach Alpha coefficient. As found in the analysis, coefficient values are high (0.88) and they are even higher if we exclude the first criterion (Cronbach's Alpha = 0.9 for Items 2-9). Therefore in the following analysis we used this new scale which comprises of ratings of criteria 2-9, has a high inner consistency and a near to normal distribution.

A *t* test on the mean of the new scale for vocal control shows significantly higher ratings under the Noise condition ($M = 0.61$ on α +3 to -3 scale) as compared to the "control" group ($M = 0$ on α +3 to -3 scale), $t = 3.00$, $p = 0.006$.

2.5 Discussion

The results of this study illustrate the positive effect of broadband background noise (running water) on vocal control and vocal production, as perceived by the singer. With such noise, the soprano singers who participated in the experiment felt more comfort and ease in terms of vocal strain, especially under known challenging conditions in Western classical singing, such as high tessitura, singing in a fast tempo, and sustaining a *piano* or *forte* high note. They reported a sense of better voice flexibility when transitioning between notes, with both fast and slow tempi (as required in Handel's aria, "*Ombra mai fu"*). They believed that they had better vocal control and that they sang more appropriately with background noise. Moreover, they perceived their vocal production or singing to be more beautiful. This was expressed not only in the rankings they gave, but also in the summarizing question at the end of the experiment and the open comments at the debriefing session following the experiment. At the end of the experiment, all the singers except one defined the presence of (clearly audible) background noise as a positive phenomenon for singing.

However, the presence of the background noise did not affect the intonation while singing. This was in fact expected, since, at these singers' advanced professional stage, the question of exact intonation does not usually arise and is viewed as a given. At the same time, it was important to make sure that the noise does not harm the singer's confidence in her intonation, since this in itself could cancel out any possible benefit of the noise regarding ease of production and its quality.

The additional criterion in which the noise is not noted as a benefit, but rather as interference, is that of, "I heard myself better". It would seem that this is a trivial result, since noise clearly has a masking effect. At the same time it is possible that it does not filter all the frequencies equally, and therefore allows the line with the tune to be conspicuous or "rise above the noise" – a sense of flexibility and hovering. "I felt my voice above the noise" – this was one participant's description at the end of the experiment.

The second stage of the study, in which we will examine the acoustic characteristics of the noise and the performances under the different conditions, will allow more in depth examination of this point. We do note in passing the methodological contribution of the study in creating a reliable scale for testing vocal production and control, based on seven criteria which underlie this important construct.

The following interesting conclusion emerges based on the findings. Although the singers heard themselves less well when there was background noise, they still reported a sense of better vocal control, more proper, correct singing, higher vocal flexibility, and more beautiful singing in general.

This result is in line with reports in the literature showing that professional singers have better vocal control than those who are not singers, under no auditory feedback conditions [14,3,15]. In addition, singers are required to sing in a variety of spaces during their career; they practice in a different environment than concert halls or opera houses and therefore learn to "translate" what they hear, or, alternatively, they learn to ignore the auditory feedback and rely on other feedback cues [3], such as kinesthetic feedback. Nonetheless, although these findings, demonstrate that singers can perform well without an auditory feedback, they do not hint to the fact that singers would prefer production with background noise, as reported in the current study.

The conditions of the current study do not allow determination of the reason for the positive effect of

background noise. But we will suggest several hypotheses based, among other things, on what the participants wrote in the preliminary inquiries section.

- The psychological effect of diverting attention from the production itself and the sound production difficulties. The words of the following two participants are in line with this hypothesis, "the background noise covered the noises of the pitch production and removed the thoughts about production, and also allowed me to listen and concentrate solely on the beautiful parts – the melody and sound"; or the following description, "in a situation with noise which was clearly audible, I felt more confidence to sing, and I didn't concentrate on listening to myself and then judging myself – things which disturb me when singing...," "it helps to 'think less' and have the voice more free", "when the exercise took place with conditions of 'beyond the threshold of audibility", I had a greater sense of freedom when singing"... Possibly the effect of diverting attention was possible also because of the uniqueness of this specific noise which is the sound of water – known as a calming sound in the field of therapy. Further testing of the effect with various types of background sounds may possibly more effectively reveal the mechanism at the base of the phenomenon

- Another intriguing albeit speculative hypothesis draws on studies showing improved performance under mild noise conditions, in detection of weak signals [16,17] and in cognitive performance especially, but not only, in children with ADHD [18,19]. A recent study showed improved recognition memory in healthy subjects under mild auditory white noise [20]. Importantly, the authors found, using *fMRI*, enhanced activity in dopaminergic areas such as the ventral tegmental area (VTA) and auditory regions (superior temporal sulcus - STS) with an enhanced connectivity between the midbrain and the right STS, possibly leading to optimal dopamine and attention levels, and better cognitive performance.

As mentioned earlier, our next step will be to ask experts to evaluate the recorded excerpts (without them knowing which piece was recorded with background noise), and to analyse both the noise as well as the recorded singing. Together these additional analyses should contribute to a better understanding of this interesting phenomenon. What is already clear at this stage is that from a subjective viewpoint, the background noise we used gives the singers a sense of better and beautiful vocal production and therefore could have significant practical implications.

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