The Effects of Stress on Singing Voice Accuracy

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Summary: Objective. The quality of a music performance can be lessened or enhanced if the performer experiences stressful conditions. In addition, the quality of a sung performance requires control of the fundamental frequency of the voice, which is particularly sensitive to stress. The present study aimed to clarify the effects of stress on singing voice accuracy.

Methods. Thirty-one music students were recorded in a stressful condition (ie, a music examination) and a nonstressful condition. Two groups were defined according to the challenge level of the music examination (first and second music levels). Measurements were made by self-reported state anxiety (CSAI-2R questionnaire) and by observing heart rate activity (electrocardiogram) during each performance. In addition, the vocal accuracy of the sung performances was objectively analyzed.

Results. As expected, state anxiety and heart rate were significantly higher on the day of the music examination than in the nonstressful condition for all the music students. However, the effect of stress was positive for the first-year students but negative for the second-year students, for whom the music examination was particularly challenging. In addition, highly significant correlations were found between the intensity of cognitive symptoms and the vocal accuracy criteria.

Discussion. This study highlights the contrasting effects of stress on singing voice accuracy but also the need to consider the challenge level and perception of the symptoms in experimental and pedagogical settings.

Key Words: Singing voice–Vocal accuracy–Anxiety–Stage fright–Stress–Music students.

INTRODUCTION

Singing voice accuracy depends on variations in fundamental frequency (f_0) during a sung performance.[1–6] In a melodic context, the relation between the tones (ie, musical intervals) and the tonal center of the melody must be respected if the performer is to be considered as singing in tune. Indeed, two kinds of errors are considered in the judgment of vocal accuracy[7]: the precision of the musical intervals and the respect of the tonality of the tune. The former is assessed by measuring the difference between each interval produced and the theoretical interval given by the musical score.[1–7] The latter is based on the consistency of the harmonically important notes performed in the course of the tune.[4] To obtain low scores for these criteria (ie, a high accuracy level), multiple components are required.[8–10] Indeed, the perceptual, motor, sensorimotor, and memory components must all function properly to control the f_0 variations in the sung performance and thus to sing in tune. Note also that there is a relationship between singing voice accuracy and the tempo of the performance for both untrained singers (the slower, the more accurate)[2,3] and professional singers (the faster, the more accurate).[4]

Most studies of singing voice accuracy have observed untrained singers in an experimental context but this condition does not reflect stage performance, which can be stressful. For instance, performing in public or under pressure (eg, in an examination) is reported to be stressful for musicians,[11] particularly in a Western classical context.[12,13] Some authors use the terms "stage fright" and "music performance anxiety" interchangeably to describe the consequences of stress,[14–16] whereas others distinguish these terms depending on the severity of the stress level.[17] The somatic and cognitive symptoms induced by a stressful situation and their interpretation by the performer can be observed by using questionnaires. For example, the performer may report perceived physiological arousal or negative thoughts and interpret them as facilitative or debilitative. Objective measurements of physiological manifestations of stress can also be observed.[11,18–25] Indeed, the heart rate is dramatically higher during a stressful condition such as a competition than during rehearsals.[18–25]

As heart rate variations have a significant influence on the f_0 of the speaking voice and sustained voice productions,[26,27] we hypothesize that a stressful condition should have an impact on vocal accuracy. However, this impact could be positive or negative. Studies of the speaking voice have shown that f_0 increases with stress,[27–30] but vocal accuracy in a melodic context depends on the relation between the notes and cannot be limited to the increase in f_0. An objective analysis of the vocal accuracy criteria would be necessary to observe the positive or negative effect of stress on the accuracy of a vocal performance. More generally, the relationship between physiological arousal and performance has been investigated since the inverted-U hypothesis of Yerkes and Dodson.[31] According to the law of Yerkes and Dodson (1908), performance increases with physiological or mental arousal and decreases when the level of arousal becomes too high. More recently, Yoshie et al[32] reported a negative change in performance quality among pianists when they performed in a stressful condition compared with without pressure. Their results did not confirm the findings of previous studies that reported no significant differences in performance quality between evaluative and nonevaluative conditions[20,24] or even an improvement under jury conditions.[22] These contrasting findings may be explained by

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a lack of control over stress, in terms of level or type. A combination of physiological and psychological measurements is thus necessary to evaluate the stress manifestations. In addition, the difference in results could depend on the challenge level of the stressful condition for the participants. In past studies, college-level music students,[22] competent,[20] skilled amateurs,[24] and highly trained pianists[32] were observed in nonstressful and stressful conditions but the implications of the context of the musical performance (ie, crucial examination or just part of the musical training) were not examined.[20,22,24,32]

To clarify the effects of stress on sung performances, the present study observed the physiological and psychological manifestations induced by a stressful situation and their effects on singing voice accuracy in music students at two levels (ie, low and high challenge levels). For this purpose, we analyzed the sung performances of first- and second-year students in a stressful (music examination) and a nonstressful condition. Our aim was (a) to confirm that a music examination represents a stressful condition through the observation of heart rate activity and self-reported state anxiety, (b) to observe the changes in the vocal performances by objectively analyzing the vocal accuracy of each recording, and (c) to compare two music levels (low vs high challenge levels) in terms of the changes in stress and vocal accuracy.

METHODS

Participants

Thirty-one music students (19 men, 12 women) from the Royal Conservatories of Belgium made up the sample. Their age ranged from 14 to 24 ($M = 19.29$). To be accepted into these institutions, music students have a singing audition, in addition to their instrumental audition. Their ability to read and sing musical scores was thus assured. The solfeggio classes are held during the first 2 years of the music program (ie, first and second levels). Note that the two solfeggio examinations are similar, with the same jury, but that the second-level examination is more important as it represents the end of the solfeggio classes, which is a condition for continuing in the music program. Eighteen participants were in their first year (aged from 14 to 24 years, $M = 19.22$) and 13 were in their second year (aged from 16 to 23 years, $M = 19.38$). Participants were instructed about the goal of the study, received an information form, signed the consent form, and knew that they could stop their participation at any time.

Procedure

The collaboration with the Royal Conservatories and the support of the teaching staff meant we could have students learn a melody during the solfeggio classes, once a week for 2 months (Learning phase in Figure 1) before the first recording. The performance was then recorded several times, with 3 weeks between sessions (Figure 1). "Habituation" corresponds to a condition which allowed music students to get acquainted with the protocol, the experimenter, and the equipment. Participants were instructed to sing the melody they had learned (Figure 2) a cappella, after hearing the first note played on a piano by the experimenter. As indicated on the score, they had to perform with repeats, at a tempo of 80 beats per minute. The melody was sung with the syllable /no/ to avoid hesitations due to the spelling of the words and to provide a clear auditory signal to segment and analyze. In the stressful condition, the participants had to sing the melody in front of a jury composed of four music experts: two solfeggio teachers, one musician with experience in solfeggio evaluation, and the pianist who accompanied the singing examination. The melody was performed at the beginning of the solfeggio examination. In the nonstressful condition, participants sang the melody in front of the experimenter in a quiet room at the Conservatories. This condition was similar to the "habituation" condition.

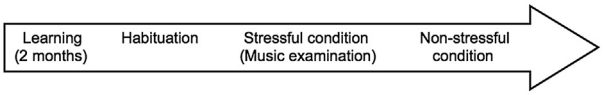

FIGURE 1. Illustration of the experimental procedure.

Material

Audio data. The melody the students learned (Figure 2) was inspired by the popular song "Happy Birthday" and created to use the criteria and analysis tools validated by Larrouy-Maestri and Morsomme.[4] Audio was picked up by a Sennheiser HS2 headworn microphone (Sennheiser, Wedemark, Germany) positioned at a constant distance of 2 cm from the right corner of the mouth and recorded on a Marantz PMD67 recorder (Marantz, Kanagawa, Japan). The sung performances were digitalized with a sampling frequency of 44.1 kHz and a 16-bit resolution.

Stress level evaluation. *Objective measurements: electrocardiogram.* Participants wore a finger sensor, linked to a DATEX OHMEDA S/5 monitor (Datex Ohmeda, Madison, WI) connected to a ThinkPark IBM laptop (IBM, Armonk, NY). The heart rate (beats per minute) was recorded in the habituation, stressful, and nonstressful conditions (Figure 1). To observe the changes in heart rate between the two conditions, we selected the nonstressful condition as a baseline and observed the difference between the stressful condition and the baseline for each participant.

Subjective measurements: questionnaire. Cognitive and somatic symptoms were assessed just before the examination

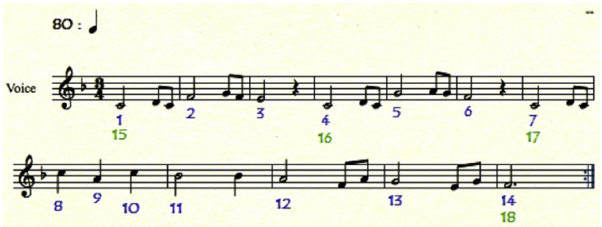

FIGURE 2. Musical score learned, recorded, and analyzed. The melodic line is composed of different intervals from the second minor to the octave, with a tonal center particularly marked in F Major. The rhythm is composed of quarter notes and half notes (crotchets are considered as ornaments). Two indications are visible: the repeat and the tempo (80 beats per minute).