Original Paper

Internal Voice Sensitivities in Opera Singers

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Abstract

To control their voices, singers rely not only on auditory feedback but also on proprioceptive feedback supplied by internal voice sensitivities (IVS). IVS, which are essentially pallesthetic (vibratory) and kinesthetic (muscular), provide singers with precise landmarks for controlling their emission. This means of control is more reliable than auditory feedback in which the voice is substantially modified by the acoustics of the environment.

Proprizeptives Feedback bei Opernsängern

Um ihre Stimme zu kontrollieren, verlassen sich Sänger nicht nur auf ihr Gehör, sondern auch auf das propriozeptive Feedback. Es ist hauptsächlich pallästhetischer (Vibrationen) und kinästhetischer (muskulärer) Natur und liefert den Sängern präzise Anhaltspunkte, um ihre Stimmproduktion zu kontrollieren. Dieser Kontrollmechanismus ist zuverlässiger als das auditive Feedback, bei dem die Stimme durch die Umgebungsakustik entscheidend modifiziert wird.

Les sensibilités internes phonatoires dans le chant

Pour contrôler leur voix, les artistes lyriques disposent non seulement du feed-back auditif mais également du feed-back proprioceptif que constituent les sensibilités internes phonatoires (SIP). Les SIP qui sont essentiellement de nature pallesthésique (vibratoire) et kinesthésique (musculaire) fournissent aux chanteurs des points de repère précis et des moyens de contrôle de leur émission plus fiables que le feed-back auditif qui subit d'importantes modifications en fonction de l'acoustique des salles.

Introduction

Opera singers and teachers of singing use the term *resonance* to refer to internal sensitivities which result from the transmission of laryngeal vibrations to the skeletal framework by means of the extrinsic laryngeal muscles. Because of their extreme importance in high-volume singing, these internal sensitivities have been described by many singers – including Lilli Lehmann [1] – in the manuals and books devoted to their art, but paradoxically, scientists have not shown much interest in them. The only exception is Husson [2], who took up on Lhermitte's study of the neurological processes underlying somatognosia

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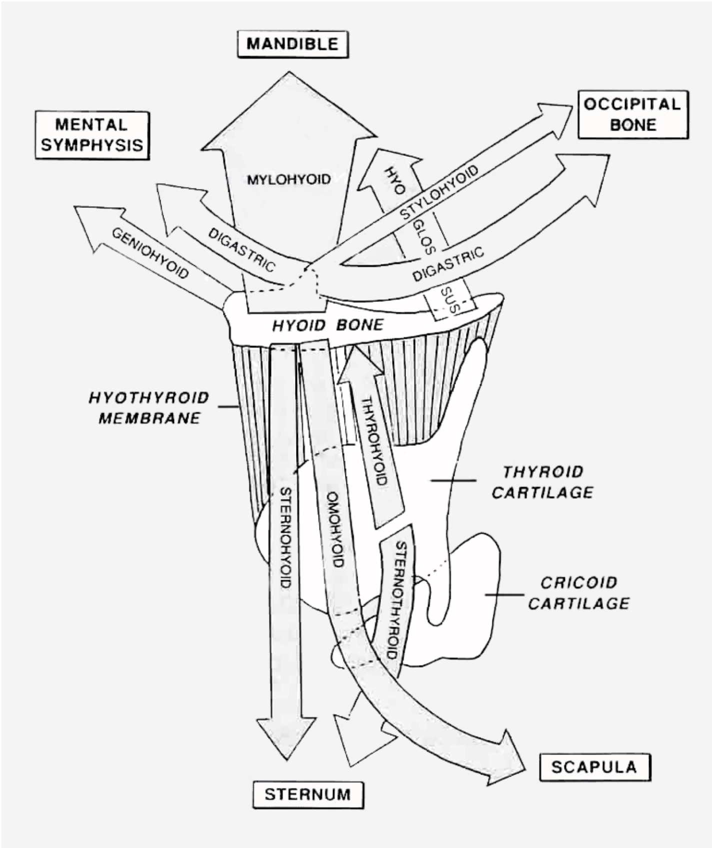

Fig. 1. Schematic representation of the main muscles which ensure laryngeal mobility in speech and singing. The presumed action of each muscle is shown as an arrow representing the direction of movement [based on ref. 10].

and examined with Soulairac [3] the phonatory function at the cortical level, before undertaking with Garde, Larger and Sebastiani a series of interesting although limited studies on internal sensitivities in the palatal[1] area. But these studies were never pursued or followed up by other researchers. Only one isolated experiment was conducted by Sundberg [4], who attempted to show that the vibrations recorded over the sternum in singers are due to subglottic pressure, not to mechanical shocks resulting from the vibration of the vocal folds, as Von Békésy [5] thought.

Origin

In the current state of the art, we cannot be sure of the physiological origin of the internal voice sensitivities. We shall therefore adopt the traditional hypothesis accepted since Von Békésy that Tarneaud [6, 7] reused in several studies: 'During singing, the vibration of the vocal folds impresses periodic shakes on the laryngeal cartilage which transmits them to

[1] By exciting the palatal area with electrical stimulation, or on the contrary, by anesthetizing it with cocaine or freezing it with ethyl chloride, Husson and his colleagues found pronounced modifications in the voice quality of professional singers which could be related to important changes in the vibratory mode of the vocal folds.

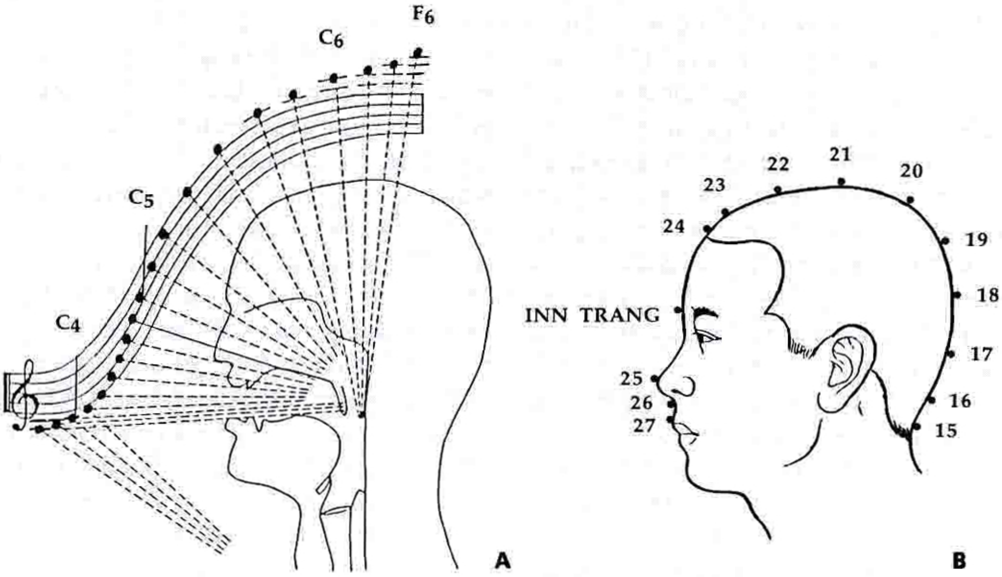

Fig. 2. Comparison between the subjective locations of the internal voice sensitivities as a function of the tessitura, for a coloratura soprano (**A**) [based on ref. 1] and the cephalic pathway of the Tou Mo meridian (**B**) [based on ref. 8].

the bones in the thorax via the laryngeal depressors, and to the bony structures in the head via the laryngeal elevators (fig. 1). Singers feel these shakes in the form of thoracic and facial vibrations.'

During singing in the lower register, the larynx is lowered by the contraction of the muscles which connect it to the rib cage (infrahyoid muscles) and relaxation of the muscles above the larynx (suprahyoid muscles). Consequently, a large proportion of the vibratory energy is transmitted to the thoracic area, giving singers the impression that their voice is *resonating in the chest.*

During singing in the upper register, the position of the larynx is raised to varying extents (relative to its resting position[2]) due to the variable degree of contraction of the laryngeal elevators. As a result, the vibratory energy is sensed in the craniofacial bone structures, and hence singers perceive their voice as *resonating in the head.* These subjective impressions are at the root of the notions of *placement of the voice* and of the expressions *chest voice, chest resonance, head voice,* and *head resonance,* used by singers and singing teachers.

Location

Depending on the pitch of the sounds produced, the *chest* and *head resonances* are spread along the singer's anterosuperior mid-

[2] Note, however, that depending on the vocal technique used, high-pitched sounds can be emitted with the larynx in the lowered position. The result is an increase in thoracic sensations and a decrease in craniofacial sensations.

sagittal plane. The *resonance* zone can extend from the sternum to the vertex (fig. 2A) or be limited to the nasolabial region. The differences observed across singers in the range of this zone, as well as in the location of the *resonance* corresponding to each note, are linked to the singer's vocal technique. Lowered-larynx techniques promote *chest resonance,* while raised-larynx techniques promote *head resonance.* Thus, in light sopranos and coloratura sopranos, for instance, where there is a high percentage of cephalization due to the use of raised-larynx vocal techniques, the *head resonance* sometimes becomes so intense that the singer feels dizzy. One possible explanation of this phenomenon can be found in Chinese medicine. When singing in the upper-middle and upper registers, light sopranos and coloratura sopranos use *head resonance* which extends along the upper pathway of the Tou Mo[3] (fig. 2B). Starting at G5 (784 Hz), which is situated at the Shen Ting level (point 24), each note has a precise location which corresponds to points 23, 22 and 21 of the Tou Mo. F_6 (1,397 Hz), sung by coloratura sopranos, is located exactly on the Baihui or Paé Roé (point 20), an extremely important point which according to Lebarbier [8] is rarely used because it can trigger a severe epileptic attack due to its direct reflexotherapeutic action upon vital brain centers (this point is prohibited in certain Chinese acupuncture schools). The same holds true for points 24, 23, 22, and 21, which are essentially neurological points used to treat dizziness, headaches, convulsions, epilepsy, etc. Hyperstimulation of these acupuncture points can therefore lead to a malaise in light sopranos.

[3] The meridian of the Tou Mo begins at the end of the coccyx (point 1), moves up along the posterior midsagittal plane, and ends at the upper lip between the two upper middle incisors (point 28).

Nature

In singing, the internal voice sensitivities are essentially pallesthetic in the craniofacial bone structures and in the thorax. They are essentially kinesthetic in the muscular groups which participate in singing, which include the postural and facial muscles and the phonatory muscles per se (respiratory, laryngeal, lingual, velar, etc.). The most intense sensations are felt in the abdominal wall and pelvic area, due to the substantial muscular activity required for breath control, and in the velar area due to the considerable activity of the velar-pharyngeal muscles in singing [9]. These sensitivities make singers highly aware of the muscular movements occurring in these areas.

Finally, it should be noted that internal voice sensitivities are practically nonexistent in the laryngeal region, except for 'light and rare sensations of an euphoric nature which are generated during high-volume emission in the upper register' (Husson) [2]. Teachers of singing play very close attention to what their students feel in the larynx, since the laryngeal sensations are usually ones of hindrance, irritation, or constriction, all sure signs of poor use of the vocal apparatus. Hence, Bataille's general principle that 'one should not feel the voice in the throat any more than one feels sight in the eye', or Thooris' saying that 'the quality of a sound is inversely proportional to the effort it expends' [both quoted in ref. 7].

Auditory Feedback

To control their voice, singers rely on two types of feedback: proprioceptive feedback provided by internal voice sensitivities and auditory feedback.

Auditory feedback is the only means of controlling one's voice under normal conditions. In speech, its essential function appears to be to control the variations in pitch which constitute intonation, a fact which explains why subjects who become totally deaf after language acquisition quickly lose control over the intonation of their speech. One might think that auditory feedback has the same function in singing, i.e. that it allows singers to control pitch and thus to produce accurate notes. But by its very nature, auditory feedback does not provide a reliable means for controlling emitted sounds. Feedback for voice control returns to the singer's ears via two distinct mediums: the air and the bones.

The term *aerial voice* is used here to refer to the voice perceived exclusively via air conduction. The term *osseous voice* is used to refer to the voice perceived solely through bone conduction.

The sound waves emitted return to the singers' ears by aerial conduction after having been modified by the acoustic characteristics of the surroundings in which they are produced. Various factors, including reverberation time, the degree of reflection or diffusion of the stage decor, the absorption coefficient of the draperies and tapestries, the type of wall and floor coverings, the room furnishings, and the percentage of occupation of the auditorium, cause some of the harmonics of the singer's voice to be reinforced while others are attenuated. These factors completely transform the timbre of the aerial voice. At the same time, the sound wave emitted by the singer is transmitted to his or her ear through the skeletal system. The vibrations produced by the phonatory apparatus during singing are conducted to the auditory nerve, either in the middle ear (by movement of the ossicular chain for frequencies above 800 Hz), the inner ear (by compression of the cochlear fluids for frequencies above 1,600 Hz), or the outer ear (by excitation of the tympanic membrane brought about by the vibration of the temporomandibular joint). Bone conduction of the osseous voice, very rich in low-frequency waves, returns the voice to the singer as if it had gone through a low-pass filter.

As they sing, then, lyrical artists simultaneously perceive their aerial voice, in which certain harmonics are reinforced or attenuated by the acoustic characteristics of the room, and their osseous voice, in which only low frequencies are amplified. The timbre of the acoustic result perceived by the singer is thus different from the timbre of the initially emitted sound wave. Yet, the timbre contains important acoustic cues indicating the placement of the voice (and is in fact the only criterion used by voice teachers to judge and correct a student's errors).

Depending on the color given to the voice by the acoustics in the room (added to the specific color of the osseous voice), singers who rely only on auditory feedback for voice control will be misled by the surprising timbre and will adjust the emission to what they hear, even in cases when it was in fact correct. To make this phenomenon clearer, let us take the example of a soprano who can only control her emission by auditory feedback and who produces an accurately pitched sound with an artistically pleasing timbre. Suppose the acoustics in the theater where the performance takes place taints the voice in such a way that she hears it as too sombre. Moreover, since the osseous voice returned via bone conduction is void of high-pitched harmonics, the 'dark tone' impression is accentuated, causing the singer to correct the emission in an attempt to 'lighten' it. For the listener, the result is a strident sound (because it is excessively light), while the singer feels she has found the true timbre of her voice. It is evident that the effective control of one's voice solely on the basis of auditory feedback is indeed very difficult.

The singer's perception of his or her own voice is not reliable enough for objective judgment of the emission. This fact poses enormous problems in learning to sing, as we shall see below.

Phono-Resonant Tuning

The basic principle governing singing consists of what Tarneaud termed 'phono-resonant tuning': to produce a sufficiently strong sound without having to furnish too great an effort, the resonance cavities, i.e. the pharyngeal cavity and the buccal cavity, must be tuned to the laryngeal sound. Tuning is achieved by modifying the shape and thus the volume of these resonators. Given the high degree of damping of the pharyngeal and buccal cavities, each mode of emission[4] has a specific resonator shape and volume. This means that for singing in the lower register, the volume of the pharyngeal-buccal resonator will amplify certain harmonics in the laryngeal sound. This will give the mode of emission its characteristic timbre: the chest voice timbre. In middle-register singing, the pharyngeal-buccal resonator will have a different volume such that another series of harmonics will be reinforced, resulting in the characteristic timbre for this emission mode: the mixed voice timbre. In the upper register, the pharyngeal-buccal cavity will have still another volume, thereby amplifying a different series of harmonics and generating the timbre specific to this mode of emission: the head voice timbre. To achieve a *homogeneous* voice in all registers, in other words, to attenuate the differences between the specific timbres of each emission mode, the resonance cavities must be adjusted gradually throughout the singer's tessitura, and not just during the *passagio* or transition from one emission mode to the next.

Learning

The singing teacher's initial role is to have students memorize the characteristic shapes of the pharyngeal-buccal cavity for each of the three registers. From there, the students can be taught how to gradually adjust the resonators as they shift from one register to the next, a task which mainly calls upon kinesthetic memory (memory for muscular movements). The next step relies more directly on pallesthetic memory (memory for the location of the most intense vibrating sensations experienced during singing). This step involves teaching students how to refine their sensitivitiy to proprioceptive voice feedback and accurately locate each note in their tessitura in accordance with their corporal schema, as defined by the vocal category and vocal technique used. The teacher must guide the students solely by ear, teaching them to associate an auditory image with an internal sensation. This practice, which is a reflex conditioning technique, allows the student over a long-term learning period (which can vary between 2 and 6 years depending on the individual) to develop the kinesthetic-pallesthetic memory required for the control of the vocal emission.

As long as this kinesthetic-pallesthetic memory has not been acquired, i.e. as long as only auditory memory is used, student singers are unable to judge their own production whenever the acoustic conditions under which they are accustomed to singing are modified. Hence, the importance of internal sensitivities in voice control. Teachers of sing-

[4] The distinction is made here between *register*, which refers to a portion of the vocal scale (lower, middle, upper), and *emission mode*, which refers to the way in which the sound is produced (chest voice, mixed voice, head voice, falsetto).

ing – who are indeed totally aware of this problem – generally ask beginners not to sing at home. Vocal work done alone in acoustic surroundings that differ from the ones students are used to during singing lessons results in faulty habits which are difficult to correct.

Use

All singers do not use their auditory memory and their proprioceptive memory in the same way. When proprioceptive memory is the predominant type of memory used, the singer adapts spontaneously to the acoustics of the surroundings, being guided by internal voice sensitivities which are not directly dependent upon auditory feedback. When auditory memory predominates (which is often the case with young singers making their debut on stage), emission problems are numerous, since, as we have seen, modifications in the singers' auditory feedback resulting from the acoustic in the theater prevent them from effectively controlling their voice.

Conclusion

Control of one's voice in singing depends both on auditory feedback, whose primary function appears to be control of pitch accuracy, and proprioceptive feedback, which plays a determining role in the control of the vocal emission. The latter allows singers to *place* their voice by providing landmarks and extremely precise control devices. Through the ongoing assessment of these internal voice sensitivities, singers become aware of their phonatory effort, can judge the quality of their emission, and to a great extent, adapt it to the current singing conditions.

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