VISUALIZATION OF CHANGE OF SOUND CHARACTERISTICS ON THE LEVEL OF THE VOCAL CORDS

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SUMMARY

The construction is reported of an apparatus for producing short stroboscopic films, employing a new phase-shifting device. This apparatus provides the clinician with a reliable record of the mode of vibration of the vocal cords (in both the opening and closing phases) alongside a tape-recording of the voice. This makes it possible to correlate recordings of the frequency and intensity and transitions of the voice with a series of stroboscopic investigations.

OPSOMMING

Die konstruksie van 'n nuwe apparaat vir die produksie van kort stroboskopiese films word bespreek. 'n Nuwe fase-verskuiwingstegniek word ingespan vir hierdie doel. Hierdie apparaat voorsien die terapeut van 'n betroubare weergawe van die wyse van vibrasie van die stemlippe (in beide oop en geslote fases), asook 'n bandopname van die stem. Dit maak dit dus moontlik om opnames van die frekwensie, intensiteit en oorgange van die stem te korrelleer met 'n reeks stroboskopiese ondersoeke.

In 1961, E. Nielsen and the author of this paper[8] reported on the construction of an apparatus for stroboscopic films.

A 16 mm-reflex Paillard Camera was modified so that continuous speeds of up to 70 pictures per second could be obtained.

The Philips stroboscope PR-1900 provided an adequate electronic flash of short duration and of great light-intensity. The optical system, with a solidly mounted laryngeal mirror which is contained in a small box, directs the light of the stroboscope to the vocal cords and transfers the picture of the vocal cords to the camera. By means of a system of mirrors and prisms, the subject of the experiment can observe his own vocal cords and make the convenient adjustments for the picture.

To be able to film the entire course of movements, it was necessary to provide the shifting of phase of the flash, from zero to 360°. At the time, this was done by mechanical means, with a subsequent 2 to 8-fold slowdown of the released light-impulses, depending on voice-pitch, up to 300 Hz. Since the flashes of the stroboscope often occurred irregularly and the mechanical change of phase was subject to a certain degree of inertia, a change to electronic change of phase was eventually resorted to.

Through a change of the optical apparatus made by the firm of Blattner and Picard, the volume of light reaching the vocal cord could be increased. The apparatus has been described in detail by Luchsinger and Pfister[6] in connection with slow-motion exposures with the use of an electro-glottograph by Cl. van Michel[6], and further explanations therefore are not necessary.

The apparatus for electronic shifting of phases was developed by the firm of Spring-Elektronik of Zürich. The frequency of the singing sound is registered by a laryngeal microphone. Special switches serve to determine the basic frequency. The stroboscope is activated by a switch which results in an increasing time-lag with respect to the basic frequency.

By means of the phase-shifts produced in this manner, a vibration of the vocal cords per one second can be observed. Since the camera can take only 70 pictures per second, frequencies in excess of 70 Hz are slowed down 4 to 8 times. Even when no sound is produced, the apparatus transmits impulses to the stroboscope. Therefore, the vocal cords are continuously illuminated. As soon as the subject of the experiment emits a sound, the apparatus automatically switches into operation, depending on the frequency of the sound. The spectrogram of the voices is determined through a "Terzbandpegelmeter".

EXPERIMENTS:

(a) Sustained sound of falsetto (e' Baritono), 280 Hz, 72 dB, Figure 1.

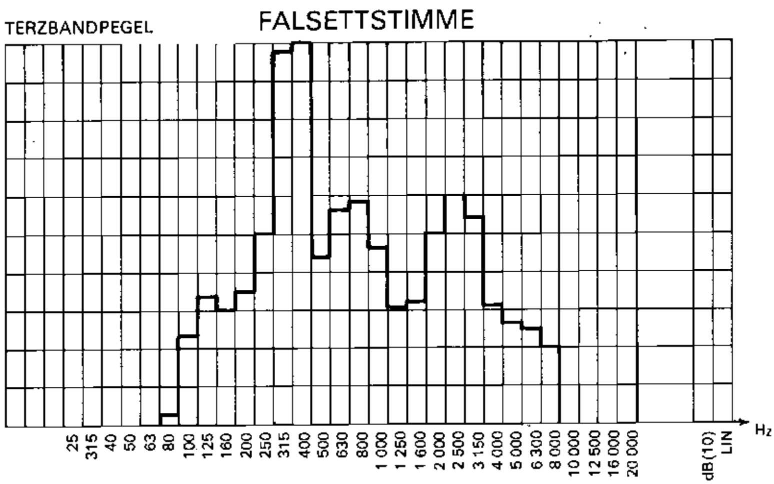

Figure 1. Sustained vowel of falsetto.

(b) Sustained sound of an alto, pitch 217 Hz and c' (261 Hz); see illustrations of voice characteristics Fig. 2 and 3.

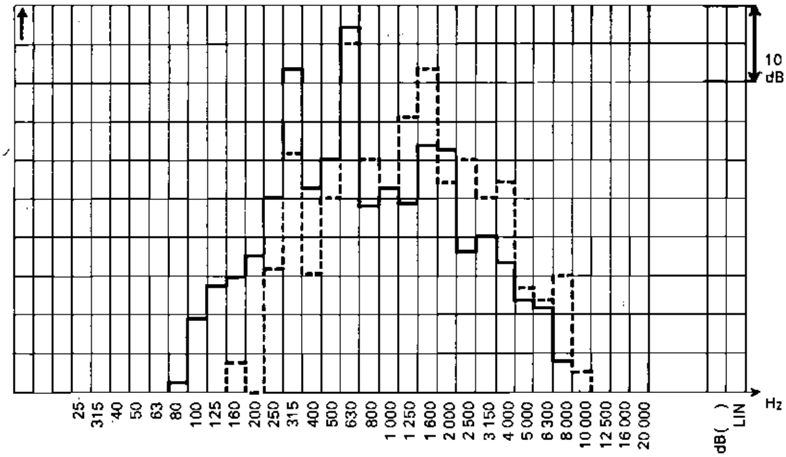

Figure 2. Alto Voice. (Transitions: dotted lines – covered voice, dark lines – uncovered voice.)

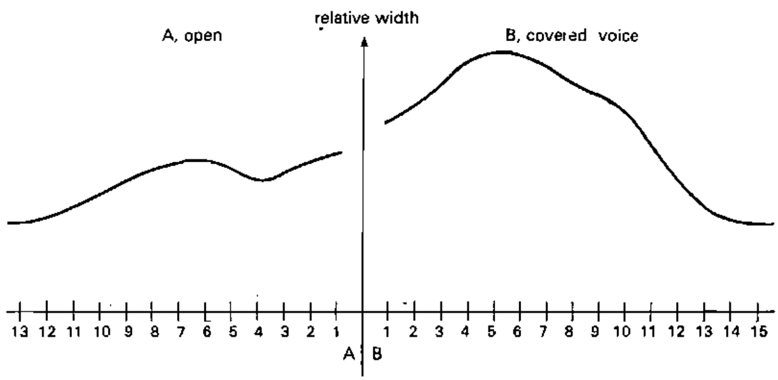

Figure 3. Alto voice, tone a (217 Hz)

(c) Attempt to obtain the change of the covered and uncovered voice of this singer on the level of the larynx, with approximately equal sound-intensity (72 decibels at 1 meter distance) vowel /ae/, which changes into a vowel nearing the /o/. The Intensity measurement was done by means of a sound-level meter of the Radio Corporation. To register the moment of change of sound-characteristics on the film the subject of the experiment had to release an additional flash at the time of the transition, which was reflected into the camera. Thus, in the course of the picture series, it can be observed whether there is an actual change in the movement of the vocal cords.

Figure 3 shows the relative opening width of the vocal cords during the so-called predominantly covered singing sound. The amplitudes of the individual pictures were measured first in the center, then likewise in the center of the measurable lateral sections of the vocal cords, and their average values were entered on the curve of relative width in millimeters.

Two series of about 50 pictures were then evaluated. Figure 2 shows the change of the sound characteristics from the open to the covered singing sound, with the distinct increase of the partial tones which has been demonstrated by various authors.

DISCUSSION OF FINDINGS: From the stroboscopic pictures one can see in the case of the falsetto (which lies opposite the high-pitched headtone and is thinner, and less expandable than the natural voice) only few partials, with an almost unchanged opening of the rima glottidis, as has been very well described by Large and co-workers.[5]

Proceeding now to the analysis of the change of sound characteristics for the above-mentioned singer (with equal pitch and of more or less unchanging voice-intensity), it must be mentioned that realization of such an intentional change in sound characteristics under experimental conditions requires a great deal of dexterity. Change of sound characteristics with 256 Hz. partial tones from beginning to end, increases the basic sound (256 Hz) and the partials appear distinctly at the time of the transition to the predominantly covered sound. But it seems important that after the transition to the covered sound the amplitudes of the vibrations of the vocal cords increase significantly. This obviously has to do with the adaptation to the higher cavities and the low position of the larynx, which has already been noted by Pielke, Arnold and Luchsinger.[7] Of interest are the findings by Husson and Dijian[3], who, in four out of five cases showed, by means of X-rays, a *distinct thinning* of the vocal cords in the case of predominantly covered singing.

There is no doubt that there also exist couplings of the higher cavities on the activity of the vocal cords, H. Rubin and Ch. Hirt[9] have found, by means of slow-motion pictures, that in the case of very high-pitched voices there appear at the time of the "edgetone" of the vocal cords waves of a riblike pattern on the surface of the mucous membrane of the voice-generator. The same phenomenon, though only in the form of thin stripes, could be observed by the writer through slow-motion film, in the case of a 14-year old boy at Sol[5] (1700 Hz).

On the basis of the electrical speech synthesis, the voice apparatus, according to Flanagan[2], can be described as a well-cushioned volume/speed-generator.

According to this theory, the vocal tract and the sound generator are not closely dependent on each other, and changes of the voice canal have insignificant influence on the vibrations of the vocal cords.

Finally, the glottographic studies of Fabre[1] should be mentioned, which Husson[4] described as early as 1960 in his book "La voix chantée". He states that the covered sound flattens the angle of the glottographic curve and at the same time increases the height of the glottogram. These studies are not in contradiction to the above-mentioned findings, but should be subject to further verification.

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