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A FIELD STUDY ON THE BODY WALL OF THE SINGER. MULTIVARIATE ANALYSIS OF 3D MEASUREMENTS FROM THE MOIRE TOPOGRAPHY

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ABSTRACT

Methods and results of a multivariate investigation of singers are presented. With complete linkage cluster analysis of the Euclidean distances between surface coordinates, similar changes of surface topography for some groups were found. The comparison with independently graded vocal quality could be interpreted in terms of more or less desirable movements.

Keywords: hierarchical classification, moiré topography, posture, motor activity, singer, 3D surface analysis.

INTRODUCTION

Individuals show characteristics when they walk, talk or sing. It is still quite difficult to tell, which specific motor activity constitutes (individual or commonly shared) features of movements. This is particularly true when singing is considered. Numerous investigations, using highly developed diagnostic methods, have been carried out on the larynx or the upper airways of single individuals and just a few vocalists. Further research in this field must naturally rely upon the harmless, non-invasive approach. One possibility is the observation of body surface changes during singing, with optical 3D measurement techniques such as the moiré method (Miles and Speight, 1975), the medical significance of which we have pointed out in this journal (Leder and Kurz, 1987).

METHOD

Ten men and four women (N=14, age 21-34 years) from a well-trained choir participated in the study. They were instructed by a member of the choir (H.K.) and gave their informed consent to data aquisition, storage and evaluation. The volunteers were asked to perform breathing exercises and to sing the tones G-d-g-d' (men; women one octave higher) in one phrase. The vocal quality was graded independently by an experienced teacher (Claudia Götting) from simultaneous tape recordings. The distinct facets of phonation were expressed by a single value ranging from 1 (no faults) to 6 (severe vocalization problems).
The principle of the Miles-Speight projected moiré method is given in Fig. 1 (cf. Kurz and Leder, 1989). Moiré fringes result from superimposition of the magnified paper print of the body upon a tranparent reference grid. Optical equipment: Liesegang slide projector with Patrinast 100mm, Canon AE-1 with Tokina 80mm. Camera-screen distance L=2m, camera-

projector distance l=0.8m. Pitch of the projected grating d=4.4mm, depth resolution (distance between moiré fringes) δz=dL/l=11mm. Agfapan 400 film was exposed for 1/8 second at aperture 8. The graphics software AutoCAD was used to digitize the moiré fringes at their intersections with square grid (node distance: 10mm) and at their points of maximum curvature.

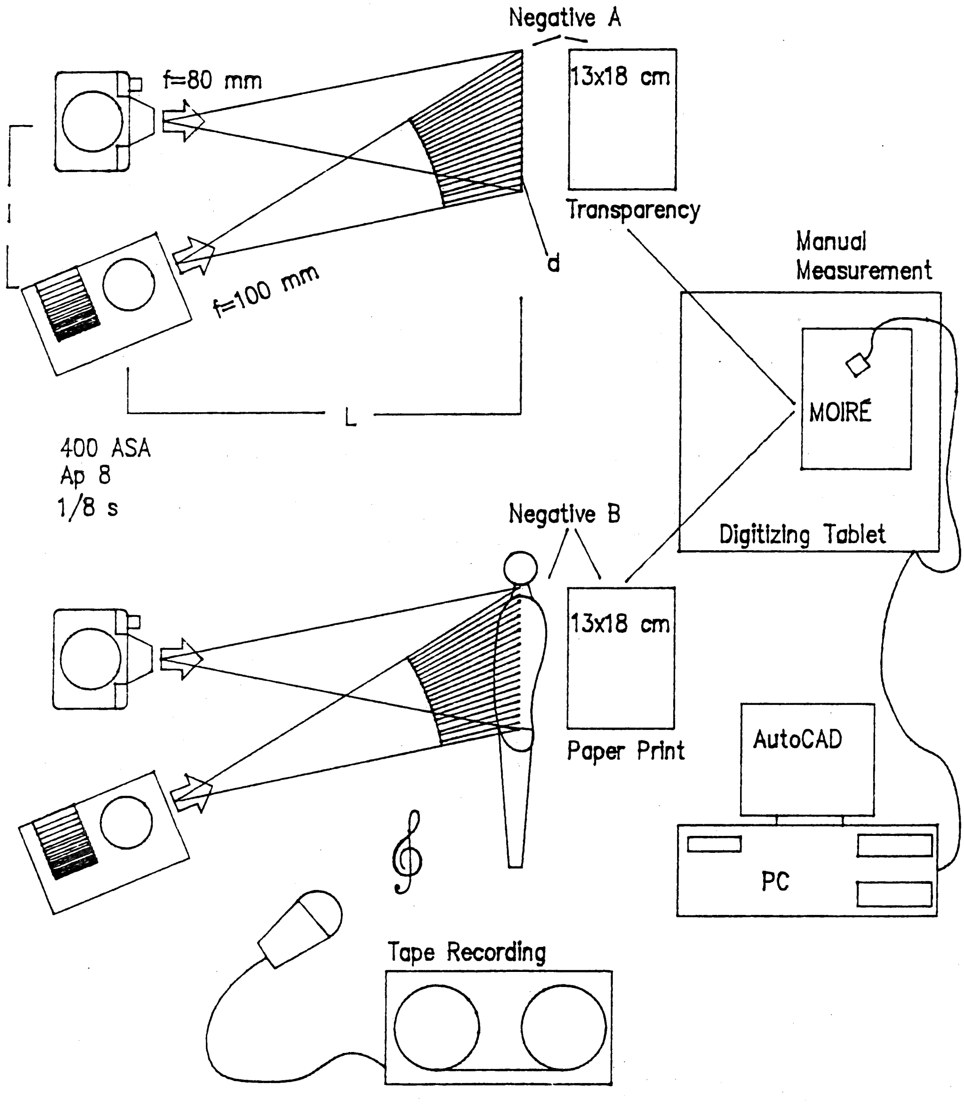

Figure 1. The Miles-Speight moiré method. A special slide, projected at an oblique angle onto a flat white screen, produces an equidistant line grating (negative A); an enlarged transparency provides the reference grid. The depth resolution δz is geometrically defined by the distances L and l, and by the pitch d: δz=dL/l. When the subject replaces the screen, exposures of the distorted line pattern on the body surface are made (negative B). Superimposition of paper prints with the reference grid generates the moiré pattern, which then was measured manually and digitized with AutoCAD; tape recordings at exposure time were evaluated later on.

The registered points are indicated in Fig. 2. Not all the coordinates could always be obtained, due to differences in body size and personal wishes. Coordinates of the anterior region of the neck (A), the back (B) and the chest and abdomen (C) from all the singers and for each posture P (inspiration, singing G, etc.) were combined into three Nxp data matrices A_P (p=5), B_P (p=9) and C_P (p=10); the constantly observed coordinates from the three regions therefore were also combined into a matrix D_P (p=13). Difference matrices between exercises then were calculated (e.g. $A_{P12}=A_{P1}-A_{P2}$), which thus corresponded to postural changes. The L_r-distances D_{kj} (r=1,2), as measures of dissimilarity between the singers (x_k, x_j), were calculated with a special TurboPASCAL program (cf. Equation (1); k,j=1..14).

$$D_{kj} = (1/p \sum_{i=1..p} |x_{ki} - x_{ji}|^{r})^{1/r} \qquad (1)$$

A NxN distance matrix could thus be obtained for any combination of exercises, and for each region A,B,C, or D. With the SAS/PC statistics package, the distance matrices were evaluated using the 'Cluster' and 'Tree' procedure. For a hierarchical classification of surface topography,

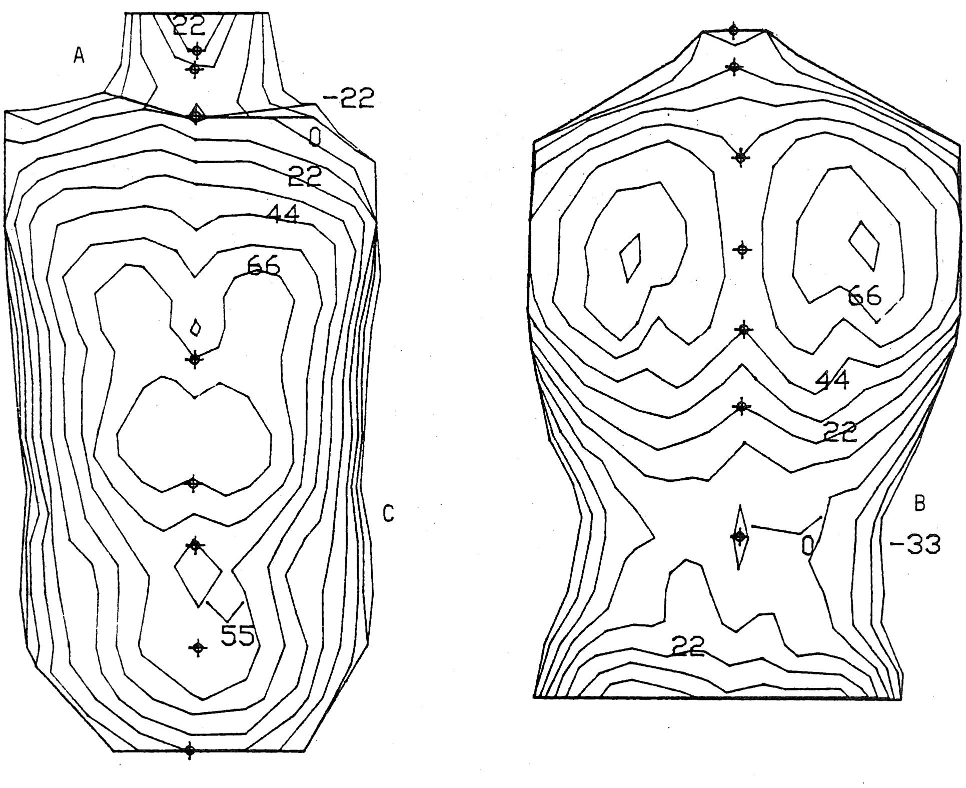

Figure 2. Digitized moiré fringes from the frontal (left) and dorsal (right) aspects of singer 6. Posture: Singing d'; Grade: 5. Lines are 11mm apart in z direction, and they can be used for a qualitative interpretation. Points indicate measurements of coordinates for the quantitative evaluation; these constitute a single row vector in the 'posture matrix' M_P (M=A,B,C,D) for each region described in the text. For other moiré patterns, see Kurz and Leder (1989).

the following agglomerative methods were applied: single, complete and average linkage, the centroid, median, and Ward's minimum cluster analysis (Bock, 1974, SAS Institute, 1988).

RESULTS

As an example of the topography of the body surface during breathing and singing, the digitized fringes are presented in Fig. 2. The thorax is held in an inspiratory, expanded position during singing. This was first described by Proctor (1964). In this paper, only the postural changes between the beginning (G) and the end (d') of the phrase G-d-g-d' are treated; this period of vocalization lasted for eight to ten seconds and was in practice equivalent to a complete expiration of the vital capacity.

Out of all the clustering methods mentioned, only the dendrograms resulting from complete linkage of the normalized Euclidean distance (L_2) are shown; single linkage produced very weak and not easily interpreted groups, and the other methods led to much the same results as complete linkage.

Fig. 3 shows the hierarchical classification for the anterior aspect of the neck (A), the back (B), the chest and abdomen (C), and for the combination of the former (D). A normalized maximum distance (between the singers) of 0.7 to 1.2 is found to define similar changes of surface topography, which in turn may be interpreted in terms of postural modification or motor activity. For example, the characteristic of the group (1,6,9) in Fig. 3 A is that the larynx rose from G to d', while (3,4,5,14) could keep it in about the same lowered position. In Fig. 3 C, the class (1,4,5,14) shares the feature of a constant position of the lower end of the sternal body, and of a moderately flattened abdomen, whereas the singers (2,3,6,12) allowed their abdominal walls to sink back further.

The grades of vocal quality are also given in Fig. 3. The best concordance between the groups and the grading can be observed for the neck (A): the more skilled members of the choir have their larynx in a lowered position when singing an ascending phrase, which is a generally accepted technique for professionals. On the other hand, a common grouping of surface alteration and singing ability is not so obvious for the frontal body wall (C), although the class (2,3,6,12) has generally lower grades than the group (1,4,5,14) or the cluster (1,4,5,7,8,11,13,14), which assembles the three grade 2 and three out of five grade 3 singers. The singer (1) obviously utilizes his body very much like the two best singers, but fails at laryngeal control.

The following groups are found for the back (B): (1,4,5,6,7) have a rather constant lumbar lordosis but diminish their thoracal kyphosis during singing, which is most obvious in (5), the possibly best singer; (8,12) have their body shifted slightly backwards, while (9,11) lean forward and seem to increase the curvature of the thoracic spine. Almost no postural modification is seen in (2,3,10,13,14). Two clusters, besides (9), may be classified for the combined coordinates (D) at a level of d=1.4: seven better singers and two less qualified are in (1,4,5,7,8,10,12,13,14), while only one moderately good singer is in (2,6,3,11). The singer (9) seems to be somewhat incompetent in several aspects of body control; to improve on his posture might therefore be a possibility to improve on his vocal ability. For singer (6) e.g., with his back in a similar postition like the best singers, it may be most useful to relax on his abdominal muscles in order to gain better control over his larynx.

DISCUSSION

On the method: The report describes body surface changes in 14 members of a well-trained choir during certain breathing and singing maneuvers. The comparability of the graphs was improved in comparison with our former publications (Kurz et al., 1989, Kurz and Leder 1989) by using normalized distances. The preference for the Euclidean distance instead of L_1 corresponds to the intention that larger differences between the singers should be stressed.

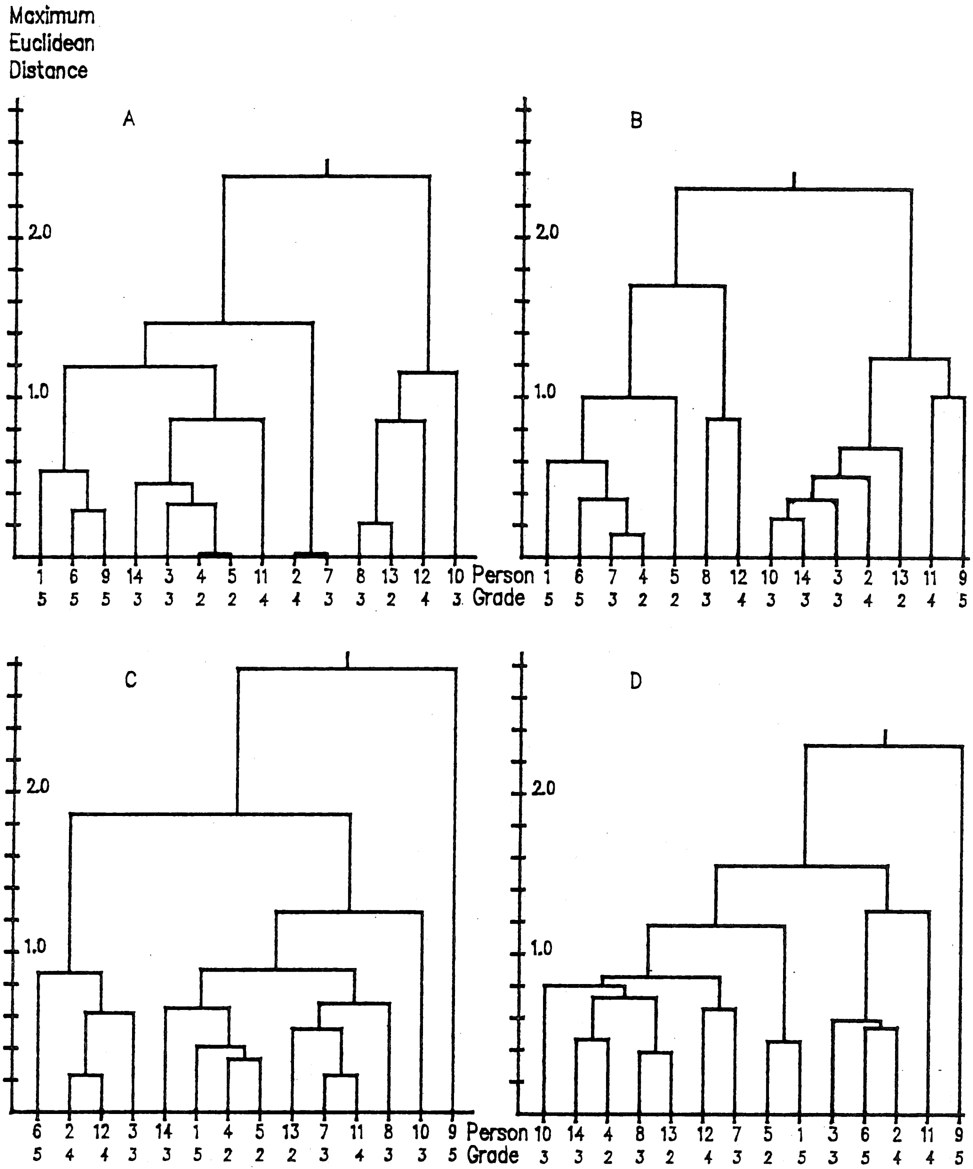

Figure 3. Hierarchical classification of the singers by postural changes between G and d'. A: anterior region of the neck; B: back; C: chest and abdomen; D: combination of coordinates from regions A,B,C. Mean values of L_2: A:10.7; B:24.9; C:20.9; D:23.9. Distances, normalized to the mean, are marked on the ordinates; the identification number of the men (1..10) or women (11..14), together with the grade of singing quality are shown on the horizontal axes. Clustering method is complete linkage: the members of a branch are no more dissimilar from each other than by the distance given for their parent node. Groups are obtained by 'cutting' the dendrograms at varying distances.

Nevertheless, using L_1 is also a reasonable approach, if the influence of posture itself and not that of postural changes is to be emphasized. Single linkage has well-known statistical properties, but often produces chained, insufficient clusters; whereas complete linkage, although not quite so well understood, insures very efficient grouping. Average linkage, or the other heuristic methods are more difficult to analyze in a statistical sense, but may well be suitable for many problems of classification. Complete linkage was preferred in this study as the most satisfying method.

On the results: While in the aforementioned papers only the ten men had been evaluated, now the four women were included. This did not change the results essentially. It is an advantage of a hierarchical cluster analysis that the influence of adding persons to the population may easily be appraised. This study seems to be the first 'field' investigation on vocalists which is aimed at observing the characteristics of skilled, non-professional singers. Different members of the choir were obviously differently trained and only a few had mastered the technique of singing with the larynx held steady at a controlled level. The postural changes, on the other side, did not lead to similarly well-defined groups, but offered a descriptive approach to understanding the body action. The varying group membership may be interpreted in terms of more ore less advantageous body actions suggesting possible techniques for improvement.

The requirements for amateurs may be certainly lower than for professionals. Moreover, the chosen tasks were not too strenuous and a better trained posture might not be absolutely necessary, although of course it is always desirable. Special attention should be paid to the neck, and for better discrimination between the singers, modifications of the exercises should be considered. The appropriate selection of coordinates may be decisive for the efficiency of the clustering algorithm (Fowlkes et al., 1988), and for the physiological interpretation of the classification. The grading of vocal performance might be refined so as to indicate the characteristics of phonation (such as intonation, duration, loudness etc.) as distinguishable attributes.

The multivariate information on both, singing quality and specific body action can provide a better understanding of the most expressive means of communication humans have ever invented, which inevitably inspires multidisciplinary research.

REFERENCES

Bock HH. Automatische Klassifikation. Göttingen: Vandenhoeck&Ruprecht, 1974:39-40,383-411.

Fowlkes EB, Gnanadesikan R, Kettenring JR. Variable selection in clustering. J Classification 1988;5:205-28.

Kurz H, Götting C, Leder O. Moiré Analyse von Rumpf und Hals beim Singen mit Methoden der automatischen Klassifikation. Verh Anat Ges 1989;84:in press.

Kurz H, Leder O. 3D measurements and 3D reconstruction of body posture. Classification of 'surface anatomy' in human beings. In: Gruen A, Kahmen H, eds. Optical 3-D Measurement Techniques. Karlsruhe: Wichmann, 1989:380-9.

Leder O, Kurz H. The Miles-Speight moiré method - Applications and prospectives in medicine. Acta Stereol 1987;6/III:763-8.

Miles CA, Speight BS. Recording the shape of animals by a moiré method. J Physics E, 1975;8:773-6.

Proctor DF. Modifications of breathing for phonation. The respiratory system III, In: Fenn WO, Rahn H, eds. Handbook of Physiology. Washington DC: American Society of Physiology, 1964:Ch 33.

SAS Institute Incorporation. SAS/STAT Guide for Personal Computers. Cary, NC: SAS Inst Inc. V 6 Ed 1987:283-357,923-40.