gegeben hat. Will man die Tonintensität von zwei Tönen vergleichen, dann sollen sie dem Ohre wie beim Wechselphonometer von MACKENZIE zugeführt werden, indem man einen knieformig gebohrten Hahn im zuführenden Schlauch schnell herumlaufen lässt.

Meinerseits habe ich versucht bei der Synthese an belasteten Stimmgabeln durch Anschlagen eine bestimmte Amplitude zu geben, doch da die Gabeln schnell ausklingen, kann nur ein Bruchteil einer Sekunde die Klangmischung dieselbe bleiben.

Elektrisch angetriebenen Gabeln geben immer Nebentöne und lassen bei den höheren Tönen keine genügende Abstufung in Klangstärke zu. Vielleicht wird es aber gelingen durch elektrische Schwingungskreise und dadurch bewegte leichte Membrane von geringem Durchmesser jede Schwingungszahl in weitgehender Abstufung hervorzubringen und dessen Intensität sei es durch Vergleichung mit den mikroptischen Gabeln, sei es durch mikrosk. Beobachtung der Membran selber zu aichen. Man hat dann den grossen Vorteil Klangquellen benutzen zu können, welche nur von einer kleinen genau dimensionierten Fläche ausgehen und deren Intensität sich während der Probe abstufen lässt.

Ist nun die mühsame Arbeit der früheren Untersucher, welche die Glyphen des Phonographen oder Grammophons analysiert haben ohne Wert? Das nicht, aber die von Ihnen gefundenen Werte sollen noch nachträglich obengenannten Korrektionen unterworfen werden.

Discussion:

Professor G. O. RUSSELL: Have you an arrangement on your tuning forks which will make it possible to vary the loudness by a known amount?
You prefer such to an electrical audiometer?

Dr. H. J. L. STRUYCKEN: Bei den jetzigen Audiometern klingt ausser die Membran auch noch der ganze Apparat mit, so dass die Entfernungsgesetze und Intensitätsgesetze nicht stimmen.

22. L. P. H. EIJKMAN, 's Gravenhage: *The Internal Aspect of the Larynx in Speech.*

In collaboration with Miss J. G. DE JONG, speech teacher at the school for hard-of-hearing children, and Dr. F. HOGEWIND, speech doctor, both at the Hague, I have experimented with Prof. RUSSELL's "Phonolaryngoscope".

Of course, the insertion of a wide tube into the mouth makes the natural production of speech sounds impossible, but on the other hand it affects but slightly, if at all, the position and condition of the organs of the larynx. Another drawback of the instrument is that strong retraction of the tongue, as in the so-called back vowels, prevents observation of the larynx almost entirely.

Our subject of experiment was Miss DE JONG throughout. This was an advantage so far that she could insert the instrument with much ease, and, owing to her thorough schooling in phonetics in the sense of SWEET, she could do exactly what she was asked to do, e.g. produce the different kinds of whisper, detach the first element from a diphthong, unvoice a soft consonant, etc. As the construction of the instrument enabled her to observe the larynx during the experiment, she could also give us her valued opinion. We, Mr. HOGEWIND and myself, experimented independently, and whenever

on comparing notes we did not agree, the experiment was repeated. If, as I have pointed out, it is desirable for the subject to have a knowledge of phonetics as SWEET understood it, it is indispensable for success in experimental research, and if experimenters would put this, in my opinion, elementary truth into practice, they would not be liable to make such blunders as some of them do now.

Owing to the very limited time allotted to me I shall have to confine myself to only a few of the questions we have investigated.

In the first place we tried to get a satisfactory answer to the question in what way the tension of the vocal cords affects the pitch of the larynx-note. (By vocal cords (Fig. 12) I understand the whole mass which projects into the glottis, i.e. the vocal ligaments and the two pairs of thyro-arytenoid muscles). To that end we transilluminated the larynx and viewed it from above with our instrument minus the light, while the subject sang an octave with her natural mezzo-soprano voice. An ordinary electric torch pressed against her neck in the region of the crico-thyroid space proved sufficient for purpose. To our surprise we found that, contrary to results obtained by the other investigators, the vocal ligaments were slightly dark at the inner edges and for the rest translucent on the lowest note, and that they became darker and darker towards the thyroid wall as the singer ascended the scale. The same effect was produced if the torch was pressed against the trachea immediately below the cricoid cartilage. This difference we at first attributed to the possibility that other investigators had experimented on males, but our observations with a gentleman as subject led to the same result. We suggest as a possible explanation that the dark edges are owing to the density of the sloping ligamentous wall of the subglottal passage, and that, as the larynx-note rises, the progressive contraction and consequent thickening of the external thyro-arytenoid muscle bulges the internal one inwards. The consequence is that the sloping ligamentous sides of the subglottal passage become more and more perpendicular, and present with the gradually thickening thyro-arytenoid muscles a denser and denser mass which becomes less and less translucent to the light from the torch. The slight relaxation of the vocal ligaments consequent upon the contraction of the thyro-arytenoid muscles is counteracted by the tilting backwards of the cricoid cartilage which regulates the necessary tension and length of the ligaments in question. With regard to the latter circumstance I may remind you of what I stated on another occasion [1]), viz., that the two plates of the thyroid

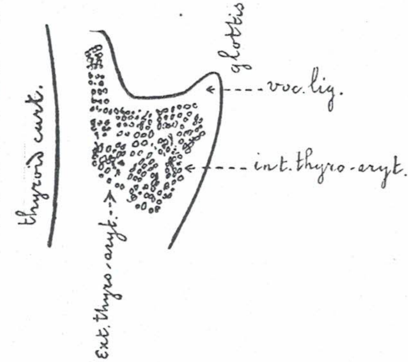

Fig. 12. Front section vocal cord.

[1]) L. P. H. EIJKMAN, Radiographie des Kehlkopfes, Fortschritte auf dem Gebiete der Röntgenstrahlen, VII, Separatabdruck, Heft 4, p. 14 (1904).

cartilage are farther apart in phonation than in the state of rest, and that they tend to move slightly inward as the note rises, thus contributing to the stretching of the vocal ligaments. What I have presented as a possible explanation attains to a high degree of probability by the result of our further experiments, viz., the transillumination of the larynx in deep [1]) breathing and in the falsetto voice. It can easily be ascertained that in deep inhalation the glottis is much wider than in ordinary inhalation. The reason of this difference appears to be that in the former case we try to make the entrance to the trachea as wide as possible, so as to admit a maximum of air. Consequently, the thyro-arytenoid muscles are moved outward by the action of the arytenoid cartilages, the ligamentous wall of the subglottal passage slopes outward as much as possible, and the vocal ligaments become translucent, except at their edges. In ordinary inhalation, on the contrary, the vocal ligaments are pretty dark all over with darker edges, all this, no doubt, owing to the fact that the vocal muscles sag, thus bulging the wall of the subglottal passage inward.

The case of the falsetto voice is very interesting, too: the vocal ligaments are very dark over their whole breadth, only the borders present each a lighter shade separated by the still lighter line of the glottis. This would seem to show that the wall of the subglottal passage is all but perpendicular, and that the edges of the vocal ligaments are exceedingly thin and sharp.

As the practice of identifying voiceless and whispered sounds seems to be spreading among phoneticians, we studied the condition of the larynx in whisper (Fig. 13, 1); and found it to be in the main as follows: the cord-glottis is all but closed and very short, and between the arytenoids there is a small triangular aperture, the cartilage-glottis. The false cords cover about one third or one half of the true ones in their full length. The epiglottis slopes more backward than in ordinary voice, and the cushion of the epiglottis bulges very much; hence, the whole aspect of the larynx is smaller than in the case of voiceless and voiced sounds.

This description also holds good for stage whisper, (Fig. 13, 2), only in a more marked degree: the epiglottis slopes more backward, the cartilage-glottis is smaller, the glottis is shorter, and the false cords leave a smaller portion of the cords proper visible, so that the whole aspect of the larynx is more compressed than in ordinary whisper.

In voiced sounds (Fig. 13, 5) the glottis is a very narrow slit which opens and entirely closes as the cords vibrate [2]), and varies in length and width with the vowel. The cartilage-glottis is quite closed. The position of the epiglottis varies a great deal, and the false cord are always well out of the way, so that the ventricles of the larynx are distinctly visible.

Then follows the glottal open consonant (Fig. 13, 4), usually represented by the letter *h* in ordinary writing. As it is best to be studied with the instrument in combination with the vowel *i:*, we have investigated successively *i:hi:* and *i:ɦi:*, both voiced and whispered. With your permission I shall only describe the two most important, viz., voiceless and voiced *h* between two voiced vowels. In voiceless *h* the glottis is an elongated, slightly fusiform or spindle-shaped

1) What is called "tief" in German, e.g. by MUSEHOLD. The glottis is a pentagon.

2) This was confirmed by the stroboscope.

slit as far as the vocal processes, which do not touch. The cartilage-glottis is exceedingly small. The false cords are invisible, and the epiglottis stands erect. In voiced *h* the true cords nearly touch, so that they can vibrate. The arytenoids tip forward over the small cartilage-glottis. For the rest there is no difference with the voiceless *h*. In voiceless *h* pronounced by itself the two glottises are much wider, and the epiglottis slopes half-way down.

As regards what SWEET calls the glottal stop and clear and gradual beginning, we have made the following observations. In clear beginning followed by *i:*, the true cords shut and, owing to the air-pressure, become convex.

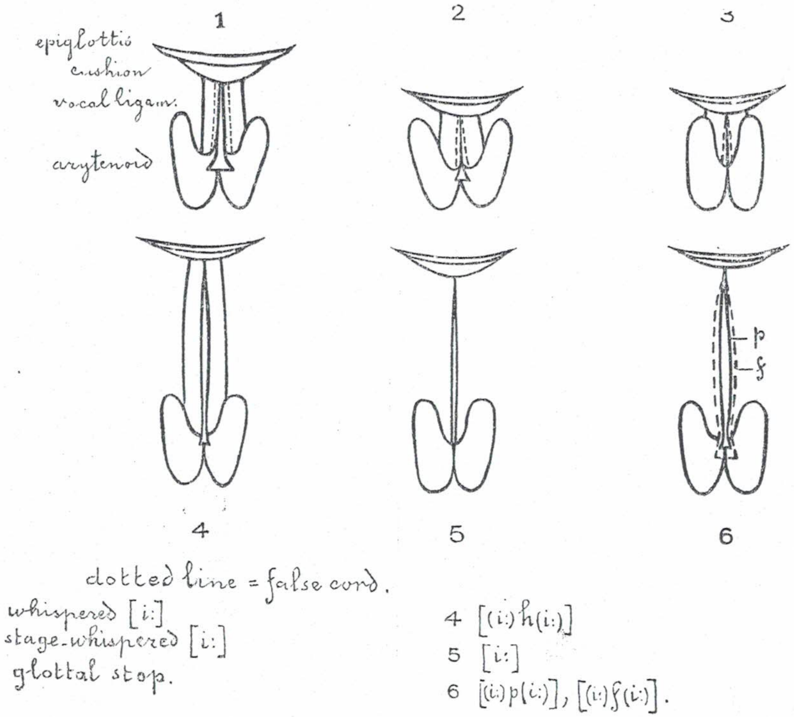

Fig. 13.

The false cords keep pretty quiet, but tend to approach each other. The epiglottis slopes half-way down and remains in that position, the arytenoids close and the side-walls of the larynx keep far apart.

The glottal stop (Fig. 13,3) at the beginning of *i:* is different from clear beginning in that the false cords cover the true cords for the greater part or even entirely, the epiglottis slopes much farther down, the arytenoids tip slightly forward, and the true cords are very short.

In the production of the vowel *i:* with clear beginning and glottal stop the first stage is as has just been described, but at the second stage (Fig. 13, 5), the explosion, the epiglottis becomes erect, and the true cords rapidly fly apart, with less force in clear beginning. Immediately afterwards the cords close again for phonation.

When the voiced *i:* begins gradually, the true cords come slowly together, touching but lightly, and remain in that position for phonation. The arytenoid glottis is also shut, the false cords are motionless in their normal position, and the epiglottis is erect and motionless.

When the whispered vowel *i:* begins gradually, the laryngeal organs glide into the required position. The epiglottis is less erect than in the voiced vowel.

It was not without satisfaction for me to find coroberation of my conclusions published elsewhere [1]) that in whisper and phonation each of the vowels has its own particular glottis area, its own particular epiglottis position, in fact its own particular laryngeal aspect, that e.g. when they are pronounced on the same note, the epiglottis slopes more and more downward in the order *i:*, *e:*, *ɛ*, *a:*. Also, as a firm believer in the possible tenseness and laxness of vowels I was glad to observe that the difference is distinctly noticeable in such pairs as *biet* and *bier*, *beet* and *beer*, *nu* and *muur*, *deun* and *deur*. The latter of each pair is produced with a slightly lower epiglottis, which corresponds with the higher note of the

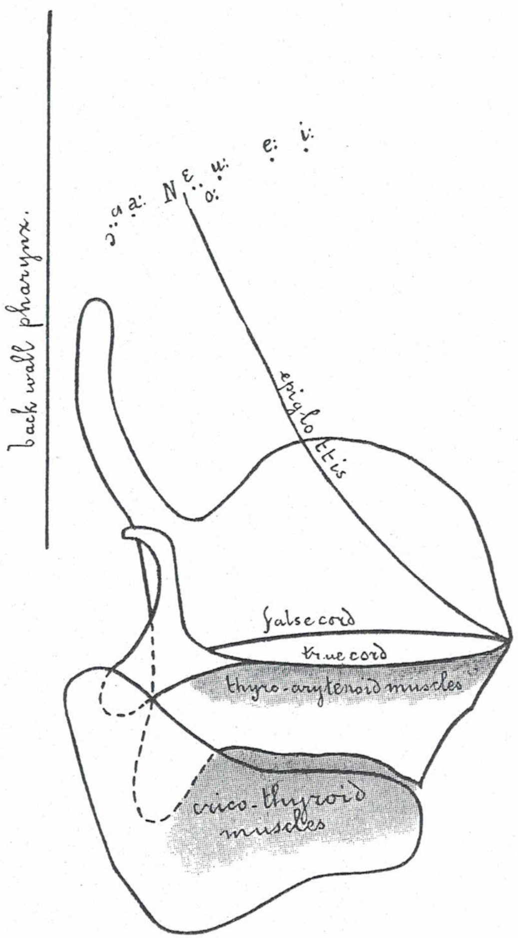

Fig. 14. Position epiglottis vowels on A from X-ray photos 1904. N = normal position.

1) The Area of the Glottis in Vowels, Engl. Studies, XL (1929). – Radiographie des Kehlk., Fortschr. etc. (1904).

back resonance cavity, just as *e:* of *beet* has a slightly more sloping epiglottis and a correspondingly higher back note than *i:* of *biet* [1]).

In the whispered vowels followed by *r*, which in my opinion are all lax ones, the cartilage glottis appears to be slightly longer drawn out, and that because the vocal cords are not so firmly closed as in the other cases. Further we found that the cartilage glottis is very small in *i:*, *y:*, larger in *e:*, *E:*, *o:*, still larger in *ɛ*, largest in *a:*. This is quite in accordance with what I have stated elsewhere. [2])

In voiced vowels the difference between tense and lax is also manifest, for in the lax ones the epiglottis slopes more downward. The true cords, besides being slightly narrower, are blunt-edged and convex, whereas in the tense vowels they are sharp-edged and flat. The glottis is in both cases only a very narrow slit, but it is somewhat wider in the lax vowels [3]). This is but natural, for a wider opening corresponds to the higher back note of these lax vowels.

Though in the so-called back vowels the root of the tongue all but prevents the observation of the larynx, yet, as regards these, too, the instrument affords a proof of the existence of tenseness and laxness, for in *o:*, *u:* of *boot*, *boet*, the entrance to the larynx is a very narrow horizontal slit which becomes wider in the vowel of *boor* and *boer*. In that of *boor* it even is so wide that the middle portion of the glottis with the arytenoids tipped forward becomes visible [4]). This difference is evidently owing to the fact that the root of the relaxed tongue does not weigh down so heavily on the epiglottis.

As regards the consonants the use of the instrument is naturally very limited. We found that the condition of the glottis is largely dependent on the accompanying vowel. What I have said about *h* between two vowels and *h* pronounced by itself also obtains for *p* and *f*. Whereas *p* and *f* pronounced

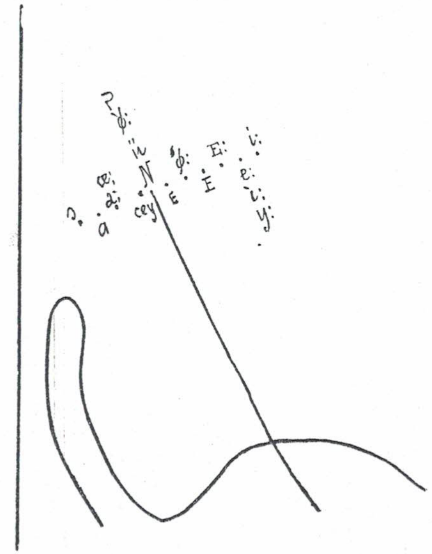

Fig. 15. Position epiglottis observed with RUSSELL's phonolaryngoscope. Dutch *pot* (ɔ), *pad* (*a*), *freule* (*œ:*), *huis* (*œy*), *deur* (ɤ:), *put* (*ü*), *bed* (ɛ), *neus* (ϕ:), *ik* (E), *beer* (E:), *nu* (*y:*), *bier* (ì:)

1) ZWAARDEMAKER en EIJKMAN, Leerboek der Phonetiek, p. 103.
2) The Area of the Glottis in Vowels, pp. 51 and 53.
3) See in this connection The Area of the Glottis in Vowels, p. 54.
4) When the subject pronounced what we considered the vowels of English *good* and *bone* (the first part), the tongue was so far relaxed and consequently the epiglottis so far raised that the cords were partly visible.

by themselves have a comparatively wide glottis, though less wide than in breathing, they show it as a narrow fusiform slit in *p* of *i:pi:* (Fig. 13, 6), and a little wider one in *f* of *i:fi:*. This slit is of course still narrower during the phonation of the accompanying vowels. The ventricles of the larynx are distinctly visible, in other words, the false cords are well out of the way.

In this connection I may be allowed to state a peculiar difference which we noted in the pronunciation of *pi:* (with voiced glide after *p*) and *fi:*. In *pi:* the vocal cords assume the position required for the vowel at the moment of explosion, whereas in *fi:*, not *i:fi:*, the narrow glottis first becomes slightly wider and then immediately afterwards narrows again for phonation. We suggest as an explanation that in preparing to say *fi:* the subject anticipating the formation of the vowel closes the glottis, but the force of the air-stream causes the cords to fly apart again for a moment. The same happens in German *p^h^i:* with voiceless glide and in *fi:* with whispered vowel. On the other hand, in Dutch *pi:* there is only air-pressure in the closed mouth, but no air-stream at the moment when the vowel begins.

In conclusion, I wish to say a word about the action of the false cords. As is well-known, they stand out in the vestibule of the larynx like two stage-wings. They have acoustic significance, in as much as they assist in keeping up and regulating the vibrations of the vocal cords proper. Apart from this function, they may in a few cases influence a speech sound by wholly or partially covering up the cords proper.

As far as they can be seen with our instrument, the false cords are perfectly quiet during a voiced vowel and voiced *h* flanked by voiced vowels. They tend to approximate during the clear beginning of whispered and voiced vowels. They partly cover the true cords in *h* flanked by whispered vowels, and during a whispered vowel, in a greater measure the stage-whispered. Finally, they cover the cords proper almost entirely or entirely during the glottal stop introducing both whispered and voiced vowels, as also during stage-whispered *i:hi:*. Hence, the difference between clear beginning and glottal stop is in this connection the degree of closure of the false cords.

Discussion:

Professor G. O. Russell: I am indebted to Mr. Eijkman, for the work he has done with my fonofaryngoskop. Since in this type of experiment it is not necessary for the subject to see his own interior larynx, I should prefer my Non-Gag Glottoskop, since it uses a tube no bigger than a match in diameter, all front vowels as well as the back are unhindered and sound natural and distinct. Since its back lens lies so well back against the faryngeal wall, one can see into the larynx on such vowels as *o*, *u*, *ə* and even *a*, when the view might be shut off in the first due to the position of the tongue and epiglottis.

Now I should like to call attention to the pulvinar as shown in these experiments of Mr. Eijkman. I seem to have been the first to note its function: twelve years ago I reported the same. You will note that in the vowels, pitch and voice-quality changes as well as in the glottal stop, coughing, gagging, swallowing, defaecation, etc., it moves towards the cartilage of Wrisberg in varying degrees of approximation or even complete closure. In other words it operates as a part of the sphincter-like closure mechanism Dr. Negus later designated.

Miss E. C. MacLeod: Request to Miss de Jong to reproduce certain sounds, namely *h*, *i:*, stage-whisper *i*, clear beginning and glottal stop in order to compare these with sounds used in Dr. Negus' and my experiments in London.

WEDNESDAY 6th JULY.

President: Professor F. Karg; Secretary: Professor J. van Ginneken.

23. Professor G. Devoto, Padova: *La Lautverschiebung e i sistemi fonologici.*

Le ipotesi più diverse sono state formulate per spiegare il fatto, apparentemente così caratteristico, della Lautverschiebung germanica: dalla rivoluzione climatica che secondo Julius Pokorny ha agito sulla laringe degli antichi Germani, al cambiamento di accentuazione che secondo Herman Hirt ha compiuto il rivolgimento in questione. È forse il momento di definire esattamente i termini del problema, prima di tentarne una soluzione.

La Lautverschiebung investe tutto il sistema delle consonanti occlusive germaniche nei suoi rapporti con la fase antecedente della lingua indoeuropea comune. Partendo dai due principi fondamentali, che nelle lingue si conservano elementi ereditari secondo le idee del P. van Ginneken e che la Lautverschiebung è il resultato di innovazioni parziali e successive, si tratta di confrontare, prima dei singoli suoni, l'organizzazione complessiva delle consonanti germaniche con quella delle altre lingue indoeuropee.

Queste ripartiscono le articolazioni consonantiche in modo diverso, secondo un criterio quadruplice nell'India, secondo un criterio duplice nell'Iran e presso Slavi Balti e Celti, secondo un criterio semplice presso Tocari ed Etei, secondo uno triplice presso Armeni, Greci, Italici e Germani. Qualunque teoria si segua rispetto al consonantismo indoeuropeo, è chiaro che il sistema tripartito rappresenta un' innovazione.

A formare questa partizione concorre non soltanto l'opposizione di consonante sorda e sonora, ma anche quella di consonante semplice e consonante accompagnata da un soffio. Ma questa associazione è per sè stessa instabile. In greco essa ha per risultato di trasformare ben presto le consonanti occlusive aspirate in fricative. Il latino presuppone ugualmente la sostituzione di una fricativa a una momentanea seguita da aspirazione. Alla base della Lautverschiebung germanica non c'è nulla di diverso da questi fatti del greco e del latino: alterazione di antiche aspirate; formazioni di consonanti fricative.

La differenza è differenza di intensità: perchè le antiche sonore aspirate hanno subito una trasformazione parallela a quella del greco e del latino, anche se si sono trasformate in spiranti sonore e non sorde; mentre da aspirazione e da affricazione sono state colpite le sorde originarie che in greco e in latino sono rimaste intatte. Ma si limita a questa semplice espressione:

Greci, Latini	momentanee	2:	affricate	1
Germani	„	1:	„	2

La legge di Verner non è che un caso particolarmente favorevole di questa alterazione consonantica: davanti all' accento, davanti cioè a una vocale particolarmente distinta, si ha una forma più evoluta di affricazione che non si limita alla continua sorda, ma arriva a quella sonora.