

Use of Palatography

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In recent years workers in the field of speech have become greatly in need of more precise data concerning the articulation of speech sounds. The present need has arisen partly because of the increased detail with which languages are now described, and partly because many research workers are currently trying to correlate the traditional articulatory descriptions of speech with the results of the new forms of acoustic analysis. A most convenient way of arriving at articulatory data is by means of palatography, which is a method for locating the points of contact between the tongue and the roof of the mouth. From these data it is possible to deduce some of the probable variations in the shapes of the vocal cavities during an utterance.

Systems of Palatography

In one of the modern forms of palatography (2), the subject first sprays a black powder on the upper teeth and the roof of the mouth (including both the hard and the soft palate), and then says the word or phrase to be investigated. Wherever the tongue touches any of the areas which have been sprayed, the black powder is removed. It is possible to see

and photograph these areas with the aid of the apparatus shown in Figure 1. With the mouth placed over Mirror A, the subject can see in Mirror B the velum, the hard palate, the alveolar ridge, and the upper teeth; consequently he can observe where there has been articulatory contact. In addition, a permanent record can be made by photographing the contact areas with the camera behind Mirror B. This technique, which is known as direct palatography (1), was used to produce the palatograms which illustrate this article.

Another system of palatography involves the use of a specially made artificial palate which is dusted with a marking medium before being put into the mouth. After the word to be investigated has been pronounced, the palate may be removed, and a note made of the regions in which the marking medium has been wiped away. It is also possible to draw or photograph the false palate if a permanent record is desired (5).

There are several points to be considered when comparing these two methods of palatography. First, the direct method has the advantage that it makes it possible to study the articulations of a large number of speakers without a great deal of preparation. The making of a good artificial palate is a skilled, lengthy process, which cannot be readily undertaken for hundreds of subjects; much of the information derived from

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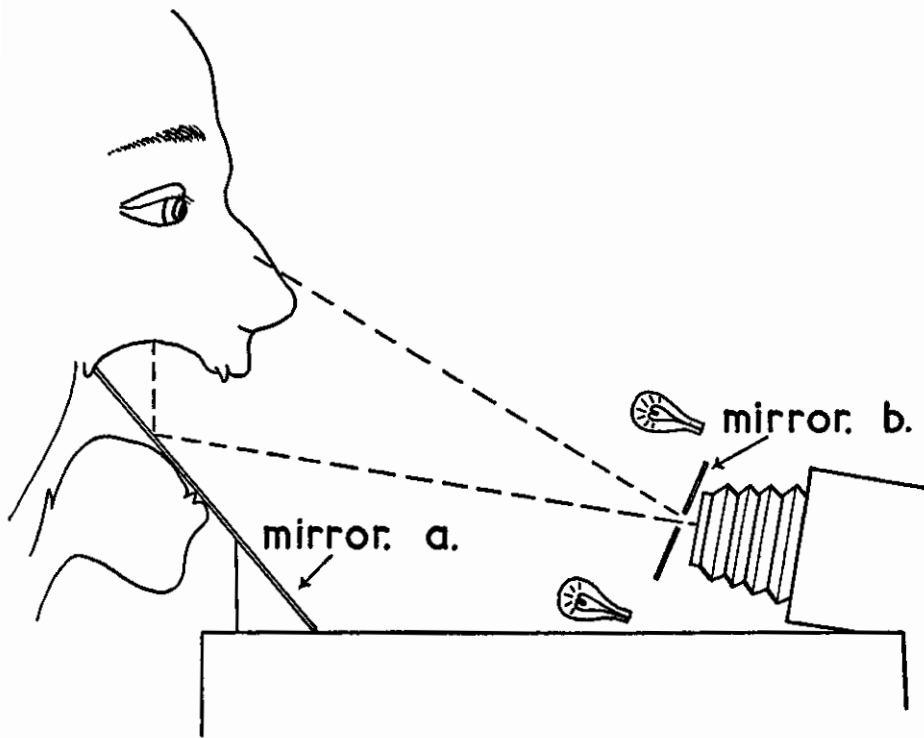


FIGURE 1. Schematic diagram of the apparatus for direct palatography.

palatographic investigations using false palates is of only limited value, because it has been based on the study of a few individuals, whose articulations may not be typical.

A second advantage of the direct method is that it need not affect the normal articulation of a sound; whereas even the finest false palate slightly alters the shape of the vocal cavities, and hence may have some effect on the action of the articulators.

Finally, the direct method enables us to study a far wider range of articulations. False palates can be made with flexible portions so that some articulations on the soft palate can be recorded; but this is not entirely satisfactory. Using the direct method it is possible to observe articulatory

contacts anywhere between the tips of the frontal incisors and the uvula.

One reported difficulty (10) with direct palatography (actually using a system slightly different from that described here) is that there may be a variation in the angle from which the photograph is taken. However, this apparent disadvantage of the system can be overcome by maintaining the camera and the mirror in a fixed relation, and ensuring that every subject places his head so that his palate is in the same position. It has also been said of direct palatography that 'because of the angle of the mirrors, prints of the palate show it slightly elongated' (2). But it has now been found that it is perfectly possible to arrange the mirrors so that the

camera viewpoint is effectively at right angles to the plane of the teeth, thus preserving the ratio between the width and the length of the palate. If the positions of the camera and Mirror A are as shown in Figure 1, the required view is obtained when the subject places his mouth over the mirror in such a way that the plane of his teeth is horizontal. The only practical difficulty is in deciding what is meant by 'the plane of the teeth' for subjects with irregular dentition.

Articulatory Positions

Whichever system of palatography is used, the results of a palatographic investigation will be articulatory data in the form of diagrams or photographs which can be archived or published. But any diagram or photograph of the palate is a two dimensional representation of information which was originally in three dimensions. A view of the palate from a point at right angles to the dental plane (which is the traditional way of presenting a palatogram) preserves the ratio between the length and the width of the palate only at the expense of giving an inadequate impression of the depth of the palate. As a result, palatograms often fail to convey important information concerning the shape and depth of the palatal cavity, and the position and slope of the alveolar ridge.

One answer to this problem is to use stereoscopic photographs. Another, which is more convenient if the data are to be published, is to accompany each palatogram with a diagram showing a sagittal section of the palate. The simplest way in which this can be obtained is by sawing along the mid-line of a cast of the mouth. Such a diagram will be in-

accurate in so far as it fails to take into account the movements of the soft palate which may be important in speech (2). But it will give a satisfactory outline of many of the important features of the roof of the mouth.

When the shape of the roof of the mouth is known, it is also often possible to deduce the probable shape of the tongue during the articulation of the consonant in an utterance. After gaining experience with palatography, the information necessary for making a very approximate diagram of the presumed position of the tongue may be obtained by comparing a palatogram with a cast of the roof of the mouth. In order to facilitate the transfer of more precise data about the positions of the tongue from the palatograms to the sectional diagrams, a contour map of the palate has to be prepared. The contours of the palate can be obtained by cutting a number of sections of a cast in the plane parallel to the dental plane, each section being at a regular distance from a fixed point such as the point on the roof of the mouth furthest from the dental plane (*i.e.*, the deepest point of the palate). When an extensive palatographic study of a particular speaker is being made, contour lines obtained in this way can be drawn on a transparent overlay which can be placed on any photograph that has been enlarged to natural size. Thus, information concerning the height of the tongue may be speedily transferred onto the sectional diagram.

Figure 2, which shows a palatogram of the author's pronunciation of *eke*, illustrates the use of this technique. Contour lines at 0.2" intervals have been superimposed on the palatogram, and corresponding lines have been drawn across the sectional diagram.

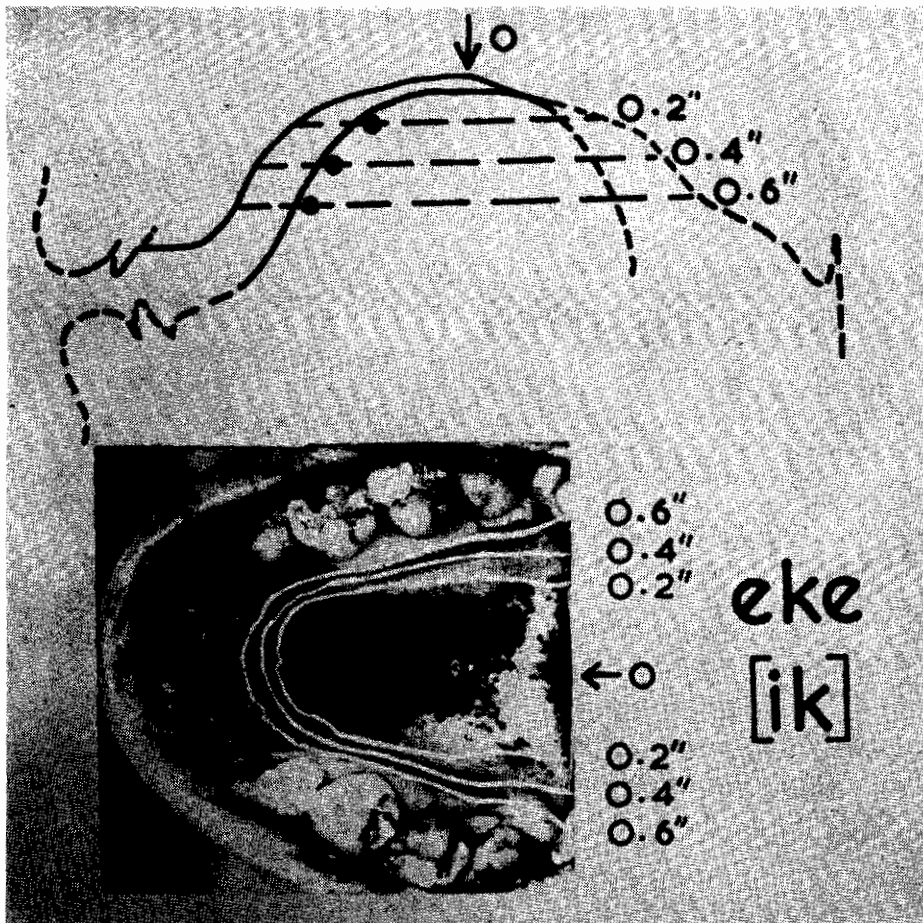


FIGURE 2. Palatogram of *eke* [ik], with superimposed contour lines at 0.2" intervals.

In this particular utterance it is probably fair to assume that most of the powder is wiped off during the articulation of the consonant. (A subsequent section of this article presents confirmatory evidence from X-ray photographs, which indicate that the body of the tongue retains an approximation to the vowel position during part of the consonant closure.) Hence the limits of the contact areas indicate the positions of the sides of the tongue at a specific moment. It

can be seen from the palatogram that the sides of the tongue have removed a considerable amount of the marking medium from the hard palate. The extent of the raising of the body of the tongue is indicated fairly accurately on the sectional diagram. The means of the points at which the sides of the tongue cross each contour line are marked by small dots; and then, on the assumption that in this utterance a cross section of the tongue would show that it is slightly domed,

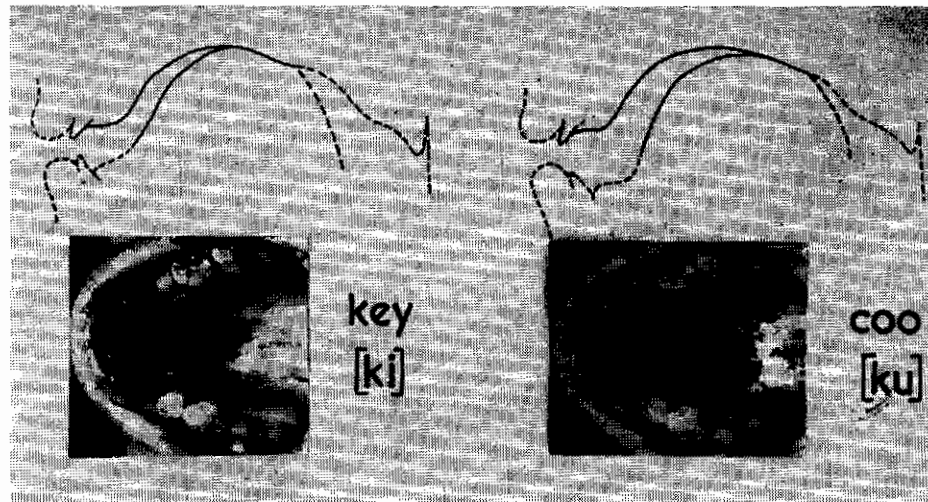


FIGURE 3. Palatograms of *key* [ki] and *coo* [ku].

the presumed position of the centre of the tongue is indicated by a line slightly above the dotted positions. In this, and in all the other diagrams accompanying the palatograms illustrating this article, positions of the vocal organs which cannot be deduced from palatographic data are indicated by dashed lines.

Selection of Utterances

In most phonetic investigations it is advisable to make palatograms showing the effect of pronouncing whole words. The resulting photograph is then a composite representation of a series of articulatory positions; but this is preferable to the artificial procedure of attempting to obtain a record of an isolated speech sound. There is always an interaction between the consecutive articulations of an utterance. Figure 3 illustrates the well known difference in the place of articulation of the plosives in *key* and

coo. The articulatory contact is clearly much further forward when the velar plosive is followed by a front vowel as in *key*. A further point of interest arises from a comparison of Figures 2 and 3, which indicates that the plosive in *eke* is not articulated in the same place as either the plosive in *key* or that in *coo*. The very advanced variety of velar plosive occurs only when it is the initial consonant in the syllable.

Figure 4 shows that there is a similar variation in the initial plosives in the words *tea* and *two*. The articulatory contact behind the frontal incisors is slightly further back when the plosive is followed by a back vowel. In view of all these differences it would seem that there is little point in trying to investigate the articulation of isolated segments of speech. Probably the most convenient way of considering a palatogram is as an aid in abstracting the articulatory features which characterize an utterance as a whole (4).

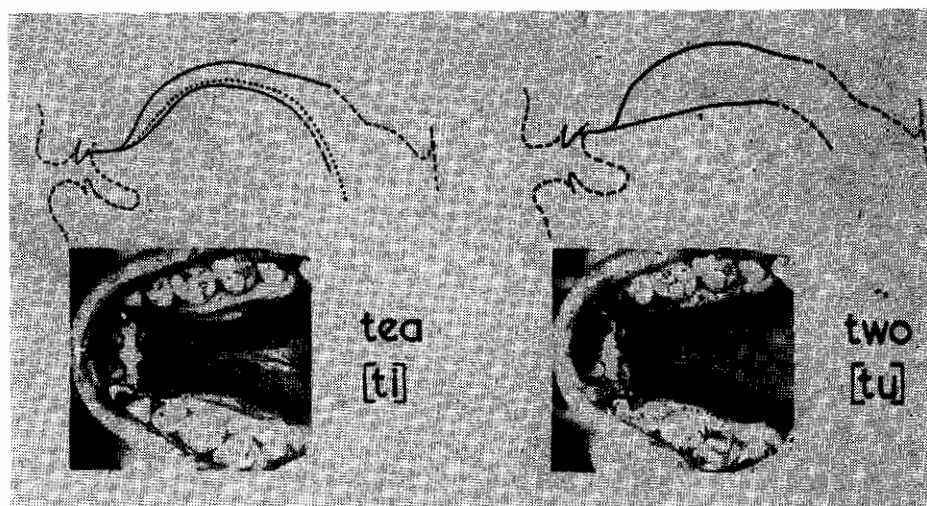


FIGURE 4. Palatograms of *tea* [ti] and *two* [tu]. The dotted line indicates the position of the centre of the tongue as shown on an X-ray photograph taken during the consonant closure in *tea*.

Comparison with X-ray Data

The articulatory features indicated in the sectional diagrams accompanying the palatograms in Figures 2-6 may be incorrect because there are two assumptions underlying the deduction of the positions of the tongue. First, it is presumed that in these utterances most of the powder was removed during the articulation of the consonant; and second, the height of the centre of the tongue is presumed to be not very different from that of the sides. As a check on these assumptions, X-ray photographs have been taken of the positions of the articulators during the author's pronunciation of the consonants in some of these words. A thin line of barium sulphate was painted on the centre of the tongue so that its position was clearly marked on the photograph.

In most of the utterances, there is a high degree of agreement between the diagrams of the position of the

centre of the tongue as deduced from palatograms and as shown on the X-rays. This agreement is illustrated in Figure 4 where the dotted line indicates the position of the centre of the tongue as recorded on an X-ray photograph taken during the articulation of the consonant at the beginning of the word *tea*. In this case, as in others, the X-ray photograph shows that even during the consonant closure the body of the tongue is approximating towards the position for the adjacent vowel.

Only occasionally do X-rays reveal major differences between the positions of the centre and sides of the tongue. These differences are of greatest importance in the study of fricatives. Thus, the articulation of [s] as in *saw* in the author's speech is as shown in Figure 5. The continuous line indicates the position of the sides of the tongue as shown by the limits of the contact areas in the

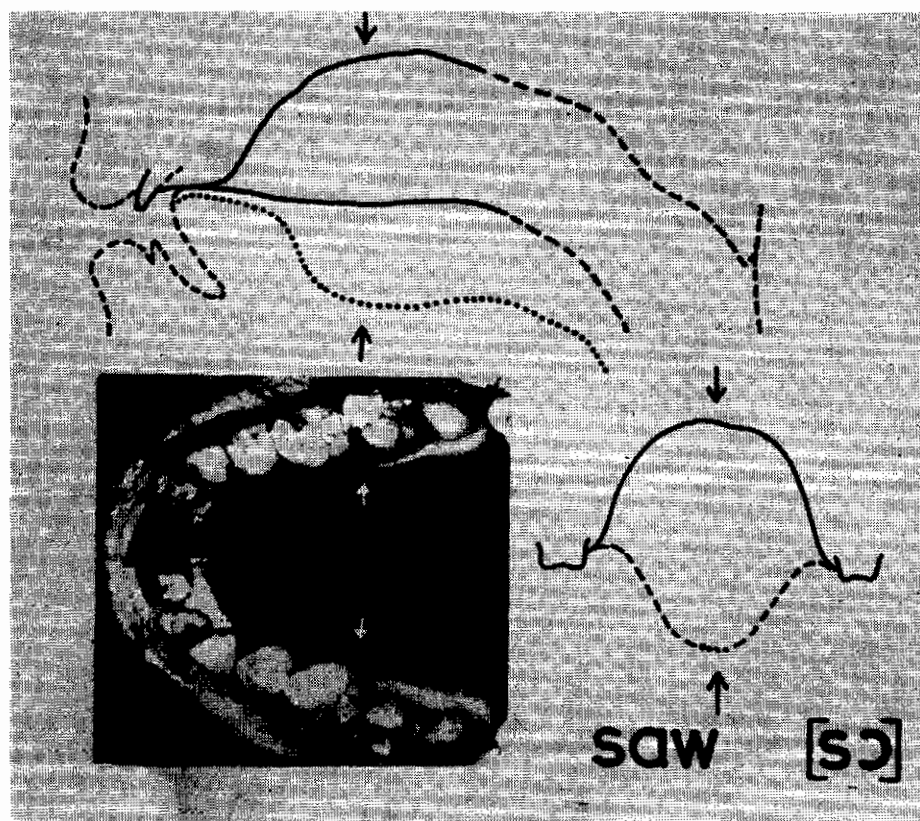


FIGURE 5. Palatogram of *saw* [sɔ]. The dotted line indicates the position of the centre of the tongue as shown on an X-ray photograph taken during the consonant closure.

palatogram (which are unlikely to be due to the vowel in this word) and the dotted line represents the data obtained from an X-ray photograph showing the position of the centre of the tongue during the fricative. These positions are typical of the author's pronunciation (which is a form of the English of England known as R.P. (7), with no marked idiosyncratic features); palatograms and X-rays showing similar positions have been obtained on a number of occasions.

It is obvious that during the author's pronunciation of the fricative [s] fol-

lowed by the back vowel [ɔ] there must be a very deep hollow in the tongue. The extent of this hollow can be seen more clearly in the transverse section of the mouth shown alongside the palatogram. This section is taken along the line joining the second molars, as shown by the arrows. Only the dashed line in this diagram indicates a presumed position; the outline of the roof of the mouth is accurately known from a section of a cast; the position of the sides of the tongue can be deduced from the palatogram; and the dotted line indicating the position of the centre of the tongue de-

depends on data obtained from an X-ray photograph. This diagram is a good illustration of the way in which palatographic and X-ray evidence supplement one another. In the examination of many sounds, the two techniques are not mutually substitutable but are complementary, each providing data which are not revealed by the other.

Description of Articulations

The data which result from a palatographic (or from an X-ray) investigation are records of different articulations. The description and comparison of such data is one of the most challenging problems of articulatory phonetics. There are two aspects to this problem: one involving the comparison of various utterances by the same speaker; and the other the comparison of the articulations of a number of different speakers.

In practice the first of these problems is relatively simple. Provided the photographs have all been taken from the same angle, and enlarged to the same size, articulations may be compared by direct reference to the palatograms, as in this article. When specific points are being singled out, an *ad hoc* reference system can be used. For example, in Figure 3 the contact in the centre of the velum during the pronunciation of the word *coo* [ku] can be said to be on the line joining the third molars; whereas that in *key* [ki] is on the line joining the second molars. Many systems of reference have been devised, most of them using the teeth as reference points (4, 8, 10). These systems are usually fairly satisfactory when comparing a number of palatograms of a single speaker with adequate dentition.

Several difficulties arise when we

try to describe and compare the articulations of different speakers. Some of these difficulties are due to misconceptions concerning the nature of phonetic descriptions. A phonetician's description of an utterance is generally the result of a process which involves listening to the speaker (and sometimes looking at him as well) and then considering the speech sounds he has produced in terms of a number of phonetic categories which owe their existence partly to tradition and partly to the particular training which each phonetic observer undergoes. Only comparatively seldom does the phonetician base his descriptions on an examination of instrumental records of the articulations of a particular speaker; such an examination invariably reveals that it is difficult to interpret instrumental data in terms of the traditional phonetic categories.

Recently much attention has been devoted to this problem from the point of view of acoustic phonetics. It is well known that it is difficult to determine the precise quality of a given vowel simply by inspection of a spectrogram which shows its acoustic characteristics. The position of the formants will give an indication of the approximate phonetic quality of the vowel; but acoustic data of this sort will not show whether a phonetician would consider it to be closer to one cardinal vowel rather than another.

It is less well known that there are similar problems in the field of articulatory phonetics. Nevertheless, difficulties have been reported by workers who have tried to correlate the traditional descriptions used in the classification of speech sounds with a mass of data obtained from palatography (10) or from X-ray photography (6). These difficulties are due to the present use of the traditional phonetic

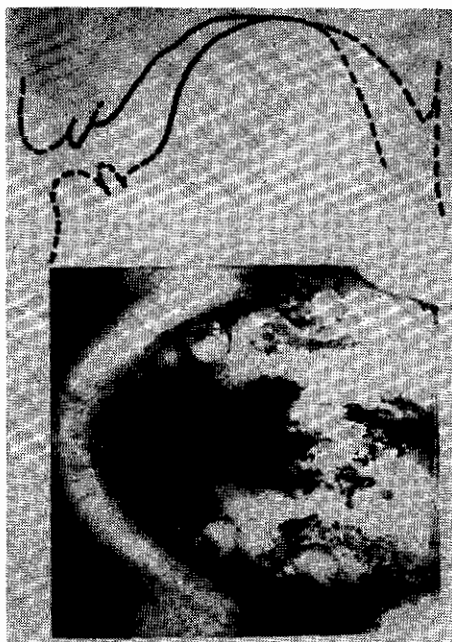


FIGURE 6. A palatogram of *key* [ki] as pronounced by a second subject.

categories, most of which originated as partial physiological descriptions. In recent years many skilled observers have been listening to utterances and then making precise classifications of the sounds involved. As a result, several phonetic terms have come to be used not as descriptions of actual articulations, but as labels for the end products of an auditory investigation.

In addition, the number of phonetic categories has increased considerably. Thus, early nineteenth century phoneticians distinguished between dental, alveolar, palatal and velar sounds; nowadays some phoneticians distinguish between dental and interdental, pre-, mid- and post-variants of each of the categories alveolar, palatal and velar, and also variants of categories such as uvular and pharyngeal. No doubt these small distinctions are necessary if we are to organize

our phonetic material conveniently and accurately. But although it may be possible and useful to make such precise auditory distinctions, it is illusory to think that these distinctions reflect equally precise articulatory categories.

Some of these problems are illustrated by a comparison of the author's pronunciation of *key* (Figure 3) and that of another subject's pronunciation of the same word (Figure 6). An examination of these two palatograms does not reveal whether these two utterances are auditorily equivalent. But all the phoneticians who heard these utterances were in no doubt that both the articulations could be classified as being post-palatal. At the moment there is no scheme of reference which will enable this information to be extracted from the palatograms. Firth (4) has suggested using the teeth as reference points from which to determine articulatory zones. But a study of a large number of subjects has shown that there is insufficient correlation between the positions of specific teeth and the positions of anatomical features, (e.g., the alveolar ridge and the highest point of the palate) which are important in determining the acoustic quality of a speech sound. In addition, there are other difficulties involved in using the teeth as reference points: several teeth may be missing, and there may or may not be gaps between the teeth which remain; sometimes the teeth (particularly the incisors) overlap; and nearly always the posterior molars are not far enough back to provide adequate reference points on the soft palate. In a survey (9) of 50 members of Edinburgh University it was found that 40% had dentition of a kind that made it difficult to use the teeth as reference points.

An alternative scheme of reference is to divide the roof of the mouth into a number of anatomically defined sections. Thus, Jones (7) defines the teeth ridge as 'the part of the roof of the mouth just behind the teeth which is convex to the tongue, the division between the teeth ridge and the palate being defined as the place where the roof of the mouth ceases to be convex to the tongue and begins to be concave.' But definitions such as these are not easily applicable in practice. As part of a preliminary investigation (9) of this problem a number of experienced phoneticians were shown mid-line sections of the roofs of the mouth of four subjects, and were asked to indicate the extent of the alveolar ridge. There were several substantial divergencies (including differences of opinion concerning the division of the sectional diagrams used to illustrate this article). But these phoneticians are all in agreement when making auditory distinctions between small variations in alveolar sounds.

It would seem, therefore, that there is at the moment no adequate way of interpreting data about the positions of the vocal organs in terms of the phonetic categories which are used in the auditory investigation of speech. There are thus limitations on a palatographic investigation (which are, of course, equally applicable to all other forms of instrumental analysis of articulations). But palatography remains one of the most useful methods of obtaining information about articulatory positions, particularly in investigations involving the detailed study of the pronunciation of a single speaker. In addition, the articulations of different speakers may be investigated by comparing the relations between the articulations which occur during the pronunciation of a series of words by one speaker with the

relations between the articulations which occur when the same set of words is pronounced by other speakers. Thus, a study of the pronunciation of the words *Tay*, *tray* and *jay* by 32 students at Edinburgh University showed that 21% made the plosive in *tray* further forward than that in *Tay*, and 18% made it more retracted; and only 6% made the contact for the plosive in *jay* appreciably further back than that in *Tay*. In another investigation a comparison of the pronunciation of the minimal pair *sip* - *ship* by 164 speakers has shown that for every speaker the articulation of the voiceless fricative in *sip* involves the formation of a narrower channel (which is usually also further forward) than that in *ship*. These studies of the relations between articulations are at the moment the most profitable way of comparing the articulations of similar sounds spoken by a number of different people.

Summary

A modern form of palatography has been reviewed in which a black powder is sprayed directly on the teeth and the hard and soft palate. Following an articulation a mirror is placed in the mouth in such a manner that a photograph can be made of the roof of the mouth, thus recording the articulatory areas in which the tongue made contact and removed the powder. Contour maps of the palate derived from casts and X-ray photographs may be employed to obtain further details about articulatory positions. From all these data it is possible to deduce some of the probable variations in the shapes of the vocal cavities during parts of an utterance. These experimental studies indicate, however, that it is difficult to correlate

physiological data about the positions of the vocal organs with the traditional phonetic categories which are used in most descriptions of speech.

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