The velarized consonants, which are quite different from the Arabic velars, follow o, ʊ, u and ɔ; about 97½ per cent. following o, ʊ, u, and the remainder ɔ. Of the centralized ə endings 82 per cent. follow ɜ or ə. Kashmiri consonants are numerous; if we count the six aspirated consonants separately we get twenty-nine, and if we count the velar, palatal, central and neutral forms as separate sounds, we get 116. Actually, however, the velar, neutral and centralized consonants closely resemble each other, and we can hardly consider them all as separate sounds. In this case we get about sixty distinct consonants altogether.

I have mentioned sound harmony. These peculiar endings affect both vowels and consonants. Thus, let us take the verb ʦʌlun, *to flee*. In Hindi it is cʌlna; the past is cʌla, pl. cʌle, fem. sg. cʌli. In Kashmiri the root is ʦʌl; but when we add the velar ending the vowel changes to o, and *he fled* is ʦolw; the palatal ending for the masc. pl. produces two other changes; the vowel becomes ɜ, and the l becomes a palatal l; so *they went* is ʦɜly; when the centralized ending is added the vowel theoretically becomes ə, and the consonant becomes ɟ; we then get ʦəɟ, which actually, however, is pronounced ʦɜɟ. It is possible to maintain that phonetically we are not concerned with these changes, for we can consider them phonetically after the change has been made, and need not worry about the change itself. This is a short-sighted view. To get a thorough grasp of the pronunciation we must think not only of the resultant sounds but of the processes by which they are developed.

It may be asked whether these special consonantal forms are numerous. Nouns and adjectives (including past participles) are subject to changes of gender and number. Of these more than half have the peculiar consonants which we are discussing.

Finally, apart from palatalized consonants, Kashmiri possesses a palatal consonant, ɲ. One is almost inclined to add ʎ (palatal l), but words never have ʎ running all through their different forms. They may have l, changed in some parts of the declension or conjugation to ʎ; whereas ɲ as an independent sound may go through all the parts of a word. We therefore get some words with n changed in parts to ɲ, and others with ɲ all through.

43. Mr A. C. Sen (Northampton, U.S.A.): *An experimental study of Bengali occlusives.*

I shall present the results of a detailed study of the Bengali occlusives, including both the aspirated and non-aspirated sounds. The study was conducted by Dr C. V. Hudgins and myself in the phonetics laboratory of The Clarke School for the Deaf at Northampton, Massachusetts.

Kymographic records of all the occlusives were made under the following conditions of utterance:

1. Syllables containing occlusives were repeated at slow rates.
2. Aspirated and non-aspirated consonants were alternated in syllables with the same degree of intensity, as nearly as possible.



3. Single syllables were repeated at increasing rates of speed from very slow up to maximum rates.
4. Syllables containing aspirated and non-aspirated consonants were grouped into rhythmic units of two to five syllables.
5. Phrases containing aspirated and non-aspirated consonants were repeated with these consonants used as releasing, arresting, median and abutting consonants.

In all the nonsense syllables the same vowel was used (indicated in the figures by a).

Tracings were obtained of the following aspects of the speech mechanism: Tracings of the buccal pressure during the consonant occlusion; voice vibrations and air pressure just outside the mouth; tracings of the laryngeal vibrations; the lip stroke for the labials; pressure and voice from the nose; vertical movements of the larynx; tension of the muscles of the pharyngeal walls; breathing movements for the phrase; syllable pulses from the chest muscles.

The data were obtained from a single subject, a native of Calcutta, whose speech may be considered as typical.

The results show that there are certain fundamental differences in the mechanism of articulation of the aspirated and non-aspirated occlusives. These differences tend to become reduced, but they persist under various conditions of utterance. This is proposed by the author as valid evidence for the statement that the aspirated occlusives are distinct phonemes, and may be considered as single sounds.

*Results*

The aspiration of the consonants is clearly shown in the tracings of the air pressure just outside the mouth. The average length of this aspiration for all the sounds studied is 0·08 second. There are no observable differences in length for any of the individual sounds when spoken at identical rates.

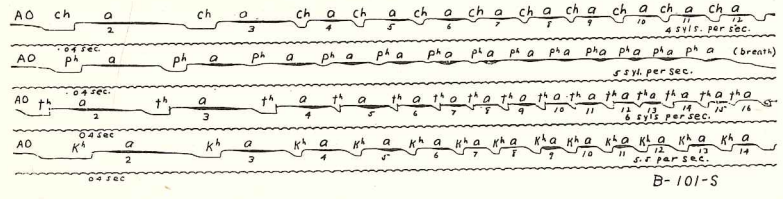


Fig. 1. Tracings of air pressure just outside the mouth for the syllables **cha**, **pha**, **tha** and **kha** spoken at an increasing rate of utterance. Time is recorded in 0·04 second.

Fig. 1 shows tracings of the four consonants **ch**, **ph**, **th**, and **kh**, in syllables spoken at an increasing rate of utterance from slow to maximum speed. The aspiratory phase of the consonants is visible in all the syllables during the slow rates but gradually decreases in length as the rate is increased, but seldom disappears.

It will be noted that the consonant **ph** behaves differently from the others as the rate is increased. At moderate rates the occlusion is

complete, but as the rate increases the occlusion becomes weaker, and at rates above four syllables per second there is a continuous flow of air from the mouth, and the occlusive **ph** becomes a fricative. Tracings of the lip strokes at this rate also show that the **ph** stroke becomes lighter. The other aspirated and all the non-aspirated occlusives show a complete occlusion at all rates of utterance.

It will be noted in this figure that the vowels in each of the syllables begin at the end of the aspiration with a very small amplitude and gradually increase to a maximum, then decline. This gives the vowel *envelope* a "spindle" shape. It will be observed later in other figures that vowels released by non-aspirated occlusives begin immediately with almost maximum amplitude. This contrasting effect of the different types of consonants upon the vowel form is evident in all tracings obtained. This gives us a clue to the difference in the acoustic quality of syllables containing aspirated and non-aspirated consonants. It is suggestive of the fact that the aspirated consonants are independent phonemes.

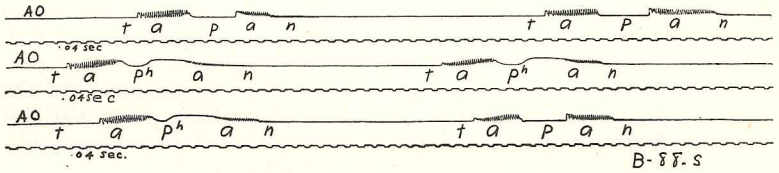


Fig. 2. Tracings of air pressure just outside the mouth for the words **tapan** and **taphan**. Time recorded in 0·04 second.

Fig. 2 shows tracings of the two words **tapan** and **taphan**. The effects of the two consonants upon the vowel form are clearly illustrated in this record. Note the clear-cut occlusion of the non-aspirated **p** as compared with the very slight occlusion of **ph**.

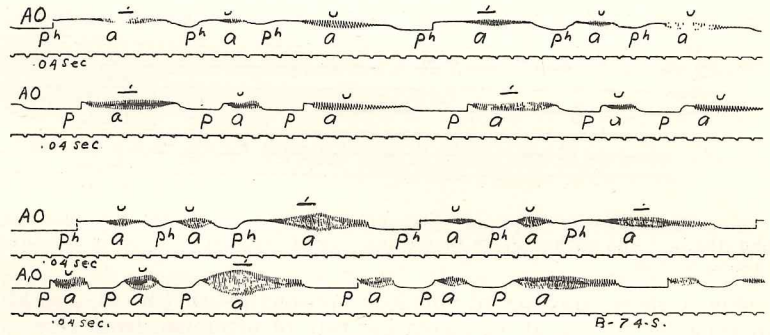


Fig. 3. Tracings of the air pressure outside the mouth for rhythmic groups of three syllables containing both aspirated and non-aspirated consonants. Time recorded in 0·04 second.

Fig. 3 shows the aspirated and non-aspirated consonants **p** and **ph** in rhythmic syllable groups with accents first on the initial



syllables and then on the third. The aspiration is retained throughout the units with **ph**, although the median syllable in each group has a much shorter aspiratory phase. The unique vowel forms are also maintained, although again, in the median syllables, which are going at a rate between five and six per second, this effect is reduced to a minimum.

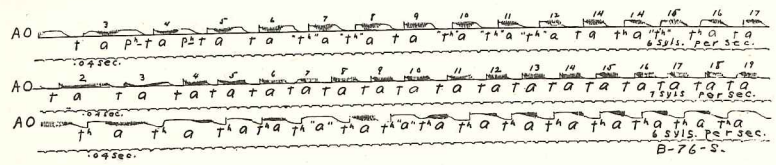


Fig. 4. Tracings of the air pressure outside the mouth for the syllables **taph**, **ta** and **tha**; all are spoken at an increasing rate of utterance. The **ph** drops out at syllable 5, but the aspiration appears in the t which becomes **th**. Time is recorded in 0·04 second.

Fig. 4 shows tracings of the syllables **taph**, **ta** and **tha** repeated at increasing speed. In the early portion of the tracing of **taph** the arresting **ph** of the one syllable and the releasing **t** of the next syllable become abutting consonants at this rate, four syllables per second. As the speed increases the **ph** drops out and the syllable becomes **ta**; but there are indications that the **t** takes on the aspiration of the absent **ph**, and the syllable becomes **tha**. Note the aspiration in syllables 5, 7, 8, 10, 12, 14 and 16. Syllables **ta** and **tha** are given below for comparison.

The differences noted above between the aspirated and non-aspirated surds also appear in tracings of the sonants. The aspiratory phase of the sonant occlusives is frequently vocalized. The amplitude of such vibrations is very small, but it is possible to observe them in 79 per cent. of the cases studied.

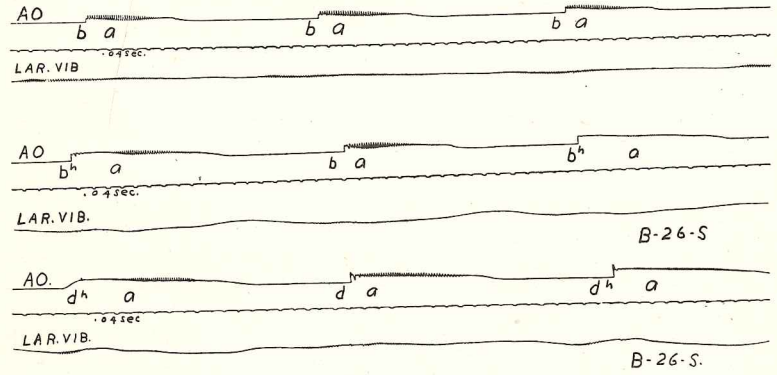


Fig. 5. Tracings of the air pressure just outside the mouth and laryngeal vibrations during the syllables **ba**, **bha**, **da** and **dha**. During the occlusion of the aspirated sonants the laryngeal tracings show a surd phase which is lacking in the non-aspirated sonants. Time is recorded in 0·04 second.

Fig. 5 shows simultaneous tracings of pressure from the mouth and tracings of the laryngeal vibrations.

*The upper record* shows the sonant **ba**; there is no aspiration and the vowel is a continuation of the vocalization of the consonant. The vowel begins with maximum amplitude. The laryngeal vibrations show continuously for consonant and vowel.

*The second record* shows the syllables **bha** and **ba** alternated. The aspiratory phase of **bh** begins with voice which appears to drop out immediately and the aspiration appears to be surd until the vowel begins. The laryngeal tracing, however, shows very slight vibrations during this phase. The vowel envelope shows the usual form for aspirated consonant-released vowels.

*The lower record* shows the syllables **dha** and **da** alternated. The same differences are clear in these tracings. The aspirated sonant occlusives of Bengali show a surd phase during the latter part of their

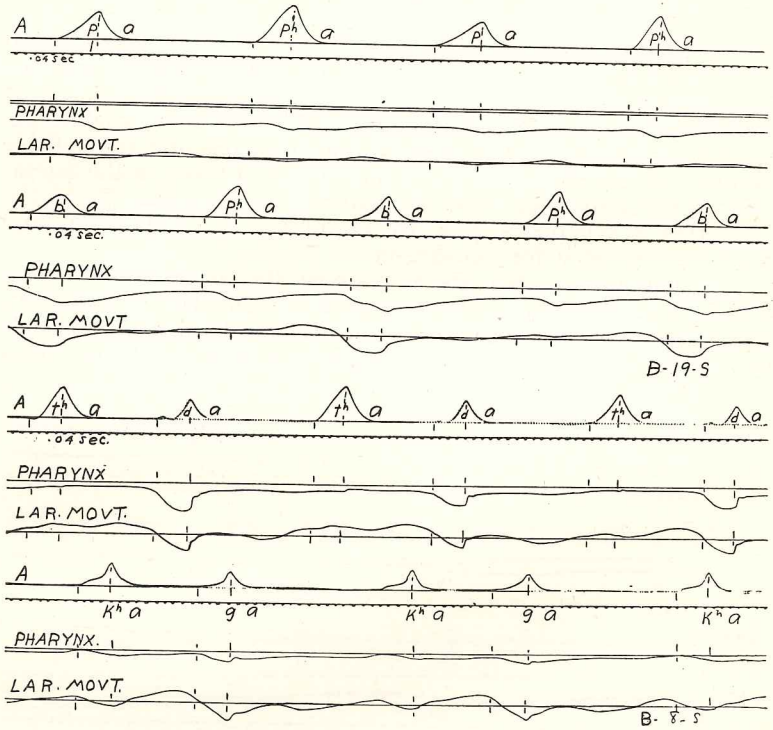


Fig. 6. Tracings of the buccal pressure, the tension of the pharyngeal walls and the vertical movements of the larynx during a series of aspirated and non-aspirated surd and sonant occlusives. The degree of buccal pressure is indicated by the height of the *A* tracings. A downward movement of the pharyngeal tracing indicates the degree of relaxation of the walls. A downward movement of the laryngeal tracings indicates a depression of the larynx. Time is recorded in 0·04 second.



occlusion much the same as the sonant occlusives of North European languages. This surd phase is lacking in non-aspirated sonants. In this respect the latter are similar to the sonant occlusives of French and other Romance languages.

A higher buccal pressure during the occlusion of aspirated occlusives seems to be a fundamental characteristic of these sounds. It distinguishes them from the non-aspirated occlusives, and is one of the factors which makes possible the heavy aspiration for the aspirated sounds. It is of interest to note the articulatory mechanism which makes this high buccal pressure possible.

It is possible to demonstrate that certain accessory movements accompany the articulation of the aspirated occlusives. These accessory movements aid in the production of the high buccal pressure and become important factors in differentiating aspirated and non-aspirated consonants.

Fig. 6 shows simultaneous tracings of the buccal pressure, the tension of the pharyngeal walls, and the vertical movements of the larynx for syllables containing both aspirated and non-aspirated consonants. This figure is a composite of two records.

The *A* tracings show clearly the difference in buccal pressure for the several consonants.

The pharynx tracing in the upper record indicates greater tension in the muscles of the pharyngeal walls during the occlusion of the **ph** than for the **p**. A downward movement of the tracing indicates a swelling in the walls.

The pharynx tracings of the other three groups show decided differences for the surds and sonants. During the occlusion of the sonants the large downward movements of the tracings indicate the relaxed condition of the muscles, while during the occlusion of aspirated surds the pharyngeal muscles are tense, and show very little movement, even though the buccal pressure rises much higher for these sounds.

The muscles of the pharyngeal walls, therefore, constrict the buccal cavity during the occlusion of the aspirated surds, and aid in establishing the high buccal pressure necessary for their proper articulation.

*The vertical movements of the larynx* are indicated in the tracing marked *Lar. Movt.* in Fig. 6. The downward movement of the tracing indicates a depression of the larynx. There are only slight differences in this tracing between the laryngeal movements during the occlusion of the aspirated and non-aspirated surds. In all records obtained, however, there are observable differences.

There is a large depression of the larynx for all the sonant occlusives, as distinguished from the slight elevation in the case of the surds **ph** and **th**.

The movements of the pharyngeal walls and the vertical movements of the larynx are part of the same general movement, the action of which tends to enlarge or to decrease the area of the oral cavity during the consonant occlusions.

When identical aspirated occlusives appear as arresting and re-

leasing consonants in adjacent syllables the two consonants *double* just as doubling occurs in other languages. When the arresting and releasing consonant are different consonants, however, the two rarely fuse to become abutting consonants. There is a tendency for the arresting member of the pair to become explosive, thus permitting the aspiration to separate it from the releasing member of the pair. This is not a case of true abutting consonants, since the vocal canal is momentarily opened between the two consonants. It is possible to force the fusion, however, by increasing the rate of utterance.

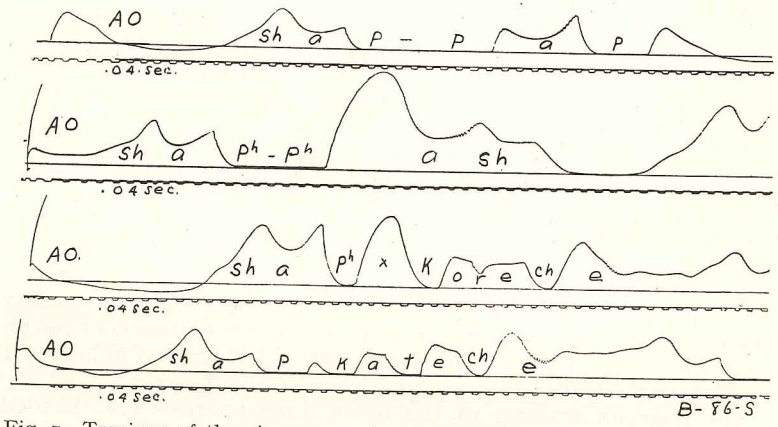


Fig. 7. Tracings of the air pressure just outside the mouth while the subject repeats phrases containing: doubles **p-p** and **ph-ph**, and the abutting pairs **ph-k** and **p-k**. The recorder used is more sensitive to pressure changes than that used in other tracings previously presented. Time is recorded in 0·04 second.

Fig. 7 shows air pressure tracings just outside the mouth, obtained with a recorder which shows air pressure as well as voice vibrations. In the upper tracing the phrase **ʃappap** shows how the non-aspirated consonants **p** double between syllables. Likewise, the phrase **ʃhaph-phaʃ** shows the same doubling form for the aspirated **ph**.

The third tracing shows the phrase **ʃaph-korece** in which the arresting **ph** explodes with a high aspiration of breath before the releasing **k** closes. This is generally the case with such combinations.

In contrast to the **ph-k** combination, the fourth tracing shows the phrase **ʃap-ketece**, in which the **p-k** form regular abutting consonants. The small amount of breath flow between the two consonants is merely the residual pressure in the mouth between the lips and the **k** position. This indicates that the releasing **k** has closed before the lips are opened; this is a case of true abutting, or linking, consonants.

Fig. 8 shows the same phrases compared with the English phrase *top-coat* in which the same abutting consonants occur. The **p-k** of English and Bengali appear very similar as abutting consonants. The **ph-k**, however, show the aspiration between syllables. This is especially apparent in the second phrase of the third tracing.



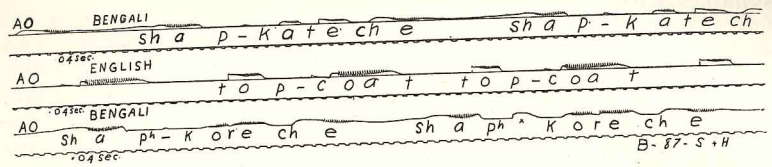


Fig. 8. Tracings of the air pressure outside the mouth showing the difference between abutting consonants **p-k** and **ph-k** in English and Bengali. Time is recorded in 0·04 second.

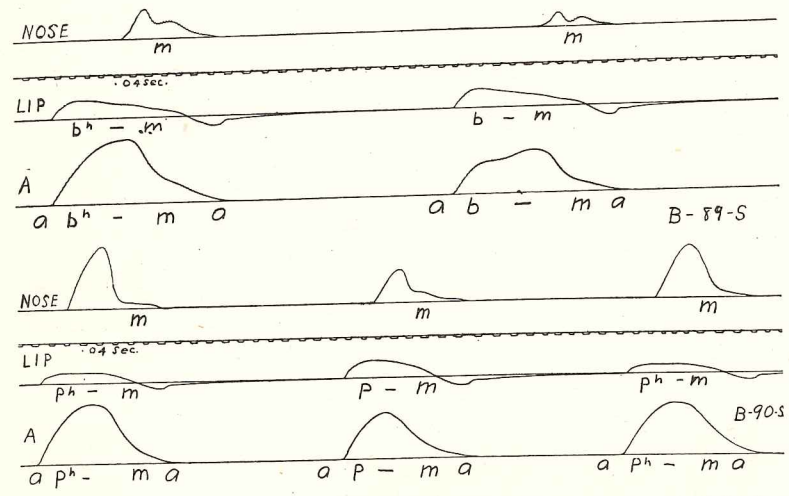


Fig. 9. Tracings of air pressure from the nose, the lip stroke for the labials **p**, **ph** and **m** and buccal pressure during the occlusion of the three consonants. The phrases spoken were **abh-ma**, **ab-ma**, **aph-ma** and **ap-ma**. Time is recorded in 0·04 second.

Fig. 9 shows another form of abutting consonants. The figure is a composite of two records, showing in the upper half simultaneous tracings from the *nose*, the stroke of the *lips*, and the *buccal pressure*, for the phrases **abh-ma** and **ab-ma**. The lower record shows the same tracings for **aph-ma** and **ap-ma**.

The lips remain closed during the pairs of consonants, but the nose tracings show the aspiration which immediately follows the opening of the velum for the articulation of the **m**. The differences in intensity of this flow of air are clearly denoted in the nose tracings. The height of the tracing indicates the degree of buccal pressure. The *A* tracing also indicates the differences in pressure for the several consonants.

Tracings of the syllable stroke of the chest muscles, obtained by means of a negative pressure recorder, indicate that the aspirated occlusives always have a heavier syllable stroke. For this reason

syllables with aspirated consonants carry the stress accent in the unit group. Objective evidence for this is found in records in which such syllables as **pha** and **pa** are alternated at normal speech rates. There is a decided tendency for such syllables to be grouped into bi-syllabic groups with the accent falling upon the syllable with the aspirated consonant. The subject finds it exceedingly difficult to give both syllables with the same degree of stress. This tendency to group syllables, and the heavier stress falling upon the syllable with the aspirated consonant, probably accounts for the loss of aspiration by the consonants in initial syllables in *reduplication*.

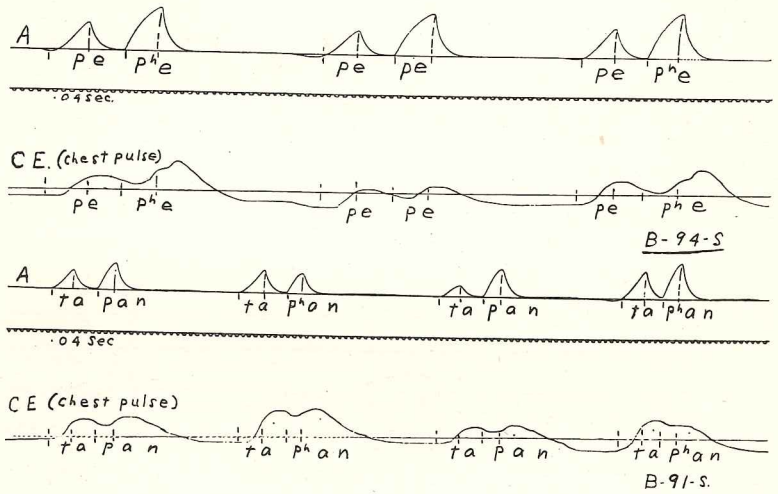


Fig. 10. Tracings of buccal pressure and negative pressure tracings of the chest pulse for the syllable during the phrases **pephe**, **pepe**, **tapan** and **taphan**. The buccal pressure is always greater for the aspirated consonant; likewise the chest stroke for the syllable containing the aspirated consonant is stronger than that for syllables containing the non-aspirated consonants. Time is recorded in 0·04 second.

Fig. 10 is a composite of two records. The upper record shows simultaneous tracings of the buccal pressure and the syllable pulse from the chest muscles (marked *CE*). The syllable groups are the reduplication forms, **pephe** and **pepe**. The second syllable in each group carries the accent, and the buccal pressure is higher for each of the consonants in these accented syllables. The syllable pulses are heavier for the syllables containing the aspirated consonants. The position of the consonant occlusions is represented on the *CE* tracings by vertical lines.

The lower record in this figure shows similar tracings for the words **tapan** and **taphan**. Again the *CE* tracing shows the heavier strokes for syllables containing the aspirated consonant. Both syllables in **taphan** appear to be stressed, while in **tapan** the accent falls upon the second syllable, but neither of the two strokes in the latter word



is as heavy as those in **taphan**, although the subject was instructed to speak them with the same degree of stress.

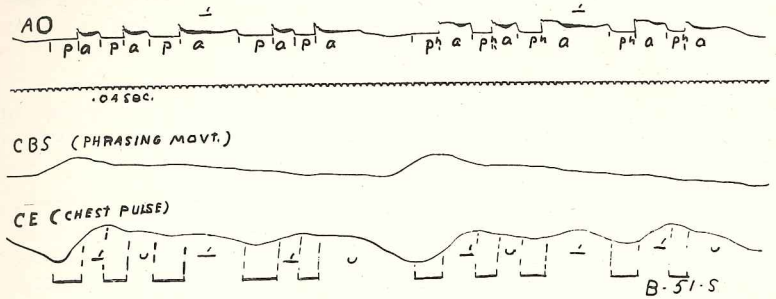


Fig. 11. Tracings of the air pressure outside the mouth, the phrasing movement and the chest pulse for the syllables. The five-syllable breath group is repeated: once with syllables containing non-aspirated and once with syllables containing aspirated consonants. The rhythm of the phrases is indicated in the tracing *CE*. The chest strokes are stronger for the syllables containing the aspirated consonants. Time is recorded in 0·04 second.

Fig. 11 shows the five-syllable phrases, the one with the syllable **pa** repeated, the other with **pha** repeated; the heavy accent falls on the third syllable in each group. The record shows simultaneous tracings of air pressure outside the mouth, the breathing movements of the chest for the phrases (marked *CBS*) and syllable strokes of the chest, *CE*. The slow expiratory movement shows clearly in the *CBS* tracing. The *CE* tracing shows that the individual syllable pulses are heavier for the second phrase than for the first.

*Conclusion*. From the evidence presented we conclude that aspirated occlusives are single sounds and independent phonemes. The following facts have been presented in support of this conclusion:

1. The vowel released by an aspirated occlusive exhibits an entirely different form in the tracings, from those released by non-aspirated consonants. This confirms an acoustic difference.

2. The articulation of aspirated occlusives is accompanied by accessory movements which aid in building up a high buccal pressure during the occlusion of these sounds. This high buccal pressure is a vital factor in the aspiration.

3. Syllables containing aspirated consonants are invariably produced by heavier syllable strokes from the chest muscles.