KINESTHETIC JUDGEMENT OF EFFORT IN THE PRODUCTION OF STOP CONSONANTS

Eli Fischer-Jørgensen

1. Introduction

Traditionally ptk are considered to be "stronger" than bdg irrespectively of the dominant phonetic difference: (i) voicelessness vs. voicing (in the narrow sense of vibrations of the vocal chords), (ii) aspiration vs. lack of aspiration, (iii) fortis vs. lenis (in the narrower sense of articulatory force) or (iv) a combination of two or all three of these differences.

In agreement with this tradition Jakobson-Fant-Halle (1952) and Jakobson-Halle (1956, 1962) combine the three differences under one feature "tense-lax", whereas Chomsky-Halle (1968) keep the three differences apart as three features, but with somewhat dubious phonetic descriptions.

In an earlier volume of this report (EFJ 1968a) I have given arguments for considering voicing, aspiration and tenseness (in the sense of fortis-lenis) as three independent phonetic features. According to this conception tense stops should be characterized by a longer closure period and a stronger organic pressure in the supraglottal cavity than lax stop consonants, whereas intra-oral air pressure is considered to belong mainly to the voicing feature.

Tenseness alone seems to be relevant in Swiss German stops, and aspiration alone in Danish stops, but I am not sure that the voicing opposition can be found without a concomitant difference of fortis versus lenis. In French the latter seems to be the primary feature (see e.g. Malmberg 1943). But even if three independent features must be recognized, the relations aspirated-unaspirated and fortis-lenis might still have something in

common, which might be called "strength" in a vague sense. It is evident that acoustically aspirated stops are strong. Physiologically they are, however, not tense in the sense used here. But how is it from the kinesthetic point of view?

2. English stops

Malécot considers American English ptk to be stronger than bdg, not only in the vaguer sense of "strong", but in the more precise sense of "fortis", i.e. having a more tense articulation in the supraglottal cavity, (Malécot 1955). This assertion is based partly on a test in which 125 students were asked to pronounce English consonants in pairs in the environment a-a and decide which of the two (e.g. p or b) required more effort (1955), partly on physiological measurements.

In the psychological test ptk were on the whole indicated to require more effort than bdg. Malécot thinks that the answers were based entirely on the action of the supraglottal organs. He bases this hypothesis (1955) on measurements showing a higher intra-oral air pressure in ptk than in bdg, and on the finding of Rousselot that t has a higher tongue-pressure compared to d. (Like Jespersen and others Malécot assumes that a higher organic pressure is needed to maintain the hold against a stronger intra-oral pressure.) His hypothesis is supported by later measurements of duration showing that ptk have a longer duration of the closure than bdg, (Malécot 1966 a and 1966 b), and of organic pressure showing that pt have a tendency to higher organic pressure than bd, although this latter difference is not significant (1966 b). Similarly Harris-Lysaught-Schwey (1965) found a tendency to stronger EMG-activity of the lips in p than in b, but no stable difference. Lubker-Parris (1971) also found a certain tendency to higher organic pressure and higher EMG-activity in p than in b, and, like Malécot, they found a constant difference in intra-oral air pressure.

On the other hand Tatham-Morton (1968 a and b) did not find any difference in the activity of the orbicularis oris between British English p and b and in Lisker's investigation of American stop consonants a clear difference in intra-oral air pressure and duration was found only in the position after a stressed vowel, whereas there was hardly any difference initially in the syllable before a stressed vowel (Lisker 1965 and 1966).

Probably Lisker's subjects had voiceless bdg in this position, whereas Malécot's and Lubker-Parris' subjects had voiced bdg. This is not stated clearly by any of the authors, but it is true of the few curves they give as illustrations (Malécot 1966 a p. 68, Lisker 1966 5.4). It is well known that there is great variability of voicing initially in English, and it is important to know whether the stops in question were voiced, since, as I have shown earlier (EFJ 1963 and 1968 a), there is a close connection between intra-oral air pressure and voicing (but not between intra-oral pressure and organic pressure).

The instability of the length difference also appears from a small number of measurements of English stops which I made some years ago. Four speakers, two British and two Americans, spoke a series of words containing stop consonants medially before stressed i a u (of the type "the part, the peal, the pool, the bark, the bean, the boom"). Voicing and duration were measured on mingograms. All had partly or fully (75-100 %) but rather weakly voiced bdg in this position.

One of the British speakers (CB) spoke the list four times in different order, which gives 12 examples of each consonant. He had a significant difference of length between ptk and bdg with a mean difference of 23 msec for p/b, 26 for t/d, and 32 for k/g. The other three speakers spoke only 6 examples of each consonant. One of the American speakers had a mean difference of 14 msec between the durations of the closures of

ptk and bdg, but complete overlapping. The two others had practically no difference. (There was, by the way, a clear tendency to have longer closures in labials than in dentals, and longer in dentals than in velars).

Now, to return to Malécot's assumption, we do not know whether the subjects used in his psychological test had voiced or voiceless bdg, and consequently we do not know whether they had higher air pressure in ptk than in bdg. Moreover, as the differences in closure duration and organic pressure are unstable, the conclusion that the subjects must have based their impression on the action of the supraglottal organs has very little foundation. On the other hand, we are pretty sure that they had aspirated ptk, and we might just as well draw the conclusion that their impression was based on this difference. A similar experiment with Danish stops might throw some light on this question.

3. Danish stops

Danish ptk and bdg are distinguished in syllable initial position only. Both are voiceless, but ptk are aspirated (and t affricated) whereas bdg are unaspirated. As for the difference fortis-lenis it is small and hardly of any perceptual importance, but phonetically bdg are slightly more fortes than ptk, in the sense that they have a tendency to higher organic pressure than ptk (this difference is significant for some subjects, but not for all)[1] and that there is a small, but stable and significant difference in the duration of the closure. As for intra-oral air pressure the pressure of ptk is only about 5 % higher than that of bdg, and only at the end

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1) An electromyographic investigation of the lip muscles is in progress.

of the closure,[2] which is less than the DL for kinesthetic judgement of air pressure found by Malécot (1966 a). Therefore, if Danish subjects find that ptk require more effort than bdg, the impression cannot be based on the supraglottal cavities.

In the years 1959-62 192 Danish students of philology (in their first term, before they had learnt anything about stop consonants) were asked to answer a questionnaire containing the following questions:

"I. Which of the two syllables in each pair requires greater effort in pronunciation? (underline the one that requires most effort, or put an equation mark if you cannot feel any difference).

a) ba or pa, b) da or ta, c) ga or ka.

II. In which of the two syllables do you apply more force to the airstream? (underline or put an equation mark)

a) ba or pa, b) da or ta, c) ga or ka.

III a) Are the lips pressed together with more strength and tension in ba or pa?

b) Is the tongue tip pressed against the upper part of the mouth with more strength and tension in da or ta?

c) Is the dorsum of the tongue pressed against the palate with more strength and tension in ga or ka?

(underline or put an equation mark)."

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2) See e.g. EFJ (1968 a). The measurements have not been published in detail, except for a bilingual subject (EFJ 1968 b). The difference of duration has been corroborated by the measurements of Danish p and b in Frøkjær-Jensen-Ludvigsen-Rischel (1971). Weaker organic pressure for aspirated stops has already been found by Rousselot for Armenian (1897 I p. 596), and the same was found for Gujarati (EFJ 1968 a, p. 96).

In an accompanying instruction it was emphasized that I was interested in their personal impression only, not in any prejudices or theories, which might probably be wrong, and they were asked to pronounce the pairs, eg. ba-pa, ba-pa a couple of times, and the same in inverse order: pa-ba, pa-ba, then papapapa and babababa at different speeds, and finally some word pairs like pande-bande, before making any decision. It was also emphasized that each question should be answered without regard to the others, and that it was by no means certain that the pairs would behave in a similar way. - Only 26 % gave the same answers to the labial, dental and velar pairs, which shows that they have really tried to make a personal judgement.

Two groups (60 subjects in all) were asked to answer some more specific questions about the articulation of t and d. As the answers to these questions required some phonetic training, it may be more or less due to chance that 55 % found that the tongue tip was more advanced in d than in t (whereas 33 % found it more advanced in t), and that 64 % found that the tip of the tongue was raised during the closure of d (and 31 % that it was lowered), whereas the percentages were equal for t (47-47). It can, however, not be due to chance that 85 % found that the teeth were closer together in t than in d.

The answers to the questions about effort gave the following results:

I Greater general effort

p 64 %	t 45 %	k 58 %
b 29 %	d 38 %	g 27 %
= 7 %	= 17 %	= 15 %

II More forceful airstream			II Stronger organic pressure		
p 83 %	t 69 %	k 76 %	p 28 %	t 17 %	k 20 %
b 11 %	d 15 %	g 11 %	b 60 %	d 78 %	g 64 %
= 6 %	= 16 %	= 13 %	= 12 %	= 5 %	= 16 %

In Fig. 1 the same information is given in graphical form.

It is evident that a great majority of the subjects feel that the airstream is more forceful in ptk, and the organic pressure stronger in bdg. In both cases there is a significant difference between ptk and bdg. This is in good agreement with physiological measurements of Danish stops.

Since ptk have a stronger airstream and bdg a stronger organic pressure, it is understandable that there is a less pronounced majority in the answers to question I about general effort. Nevertheless the differences between the reactions to p versus b and k versus g are significant. The uncertainty about t-d can be explained by the strong affrication of t which implies that it has a relatively weaker organic pressure and less strong airstream, and this is also reflected in the answers to questions II and III (t also has a shorter closure than p and k). The answers show that the feeling of general effort is influenced both by organic pressure and by airstream, but more by airstream. If the influence was about equal, we should expect t to have less general effort than d, and p and k to have a smaller majority for stronger effort.

In order to see whether there might be geographical differences in the answers, the subjects were divided into four groups according to geographical origin: (i) Copenhagen and suburbs (131), Zealand apart from Copenhagen (25), Funen (8), Jutland (28). The configurations were, however, almost the same in all groups with small variations only.

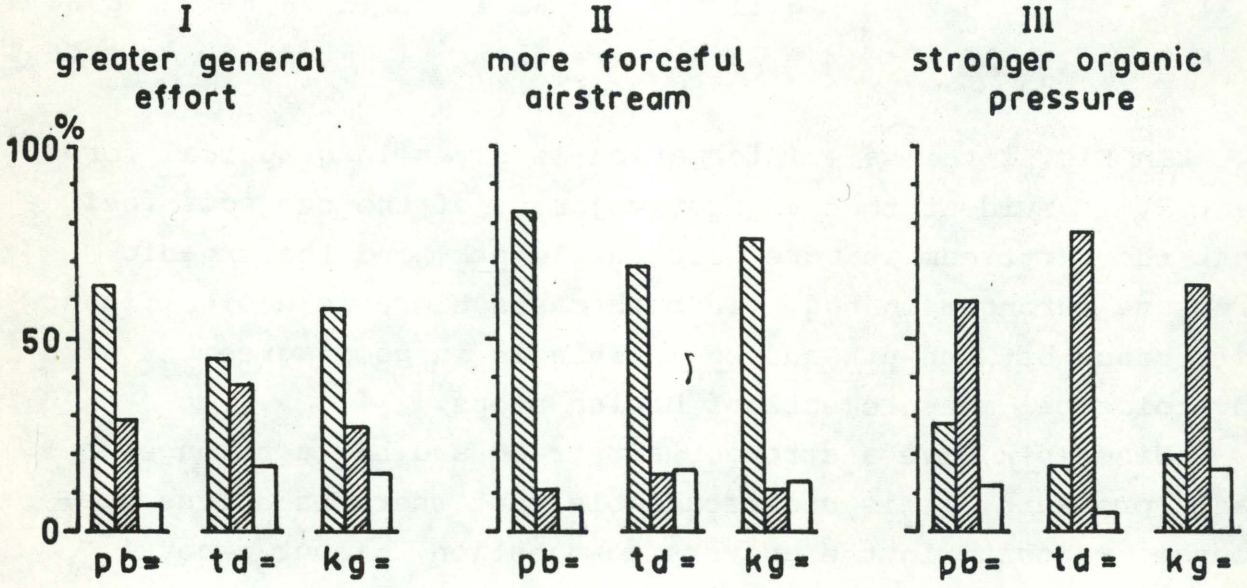

Fig. 1.

Answers to the kinesthetic test (in percentage). N=192.

The most prominent difference was in the answers to question I. Only the Copenhagen group had a significant difference between k and g, and only Copenhagen and Zealand between p and b. A closer inspection of the Copenhagen group showed a further difference between central Copenhagen + western suburbs and the northern suburbs of Copenhagen. I had expected the central Copenhagen group to be more different from the rest because of the strong affrication of t, but, on the contrary, the subjects from the northern suburbs differed most from the rest.

In Fig. 2 the subjects have been divided into three groups giving the most pronounced differences: (1) Northern suburbs of Copenhagen, (2) Central Copenhagen and Ze land, (3) Funen and Jutland. - It appears from the graphs that there are hardly any differences to questions II and III, although Funen and Jutland have a very slightly lower majority for bdg with respect to organic pressure, and Copenhagen + Zealand a slightly lower majority for ptk with respect to airstream. There are, however, clear differences in the answers to question I. Subjects from the northern suburbs have a clear and significant majority for stronger effort in ptk; Copenhagen + Zealand have a somewhat smaller difference, but it is still significant for p and k, whereas the differences for Funen and Jutland are small and reversed for t-d. - The differences cannot be easily explained from the answers to the two other questions. For the first two groups (and particularly group 1) the airstream has a stronger influence on the judgement of general effort than the organic pressure, for group 3 (Funen and Jutland) the airstream does not seem to have a decisive influence on the judgement of general effort, although it is felt very clearly as a separate phenomenon (question II). Group 2 (central Copenhagen) has a strong affrication of t and partly of k, which impedes the airstream, whereas members of group 1 have often less affrication and therefore a less impeded air-

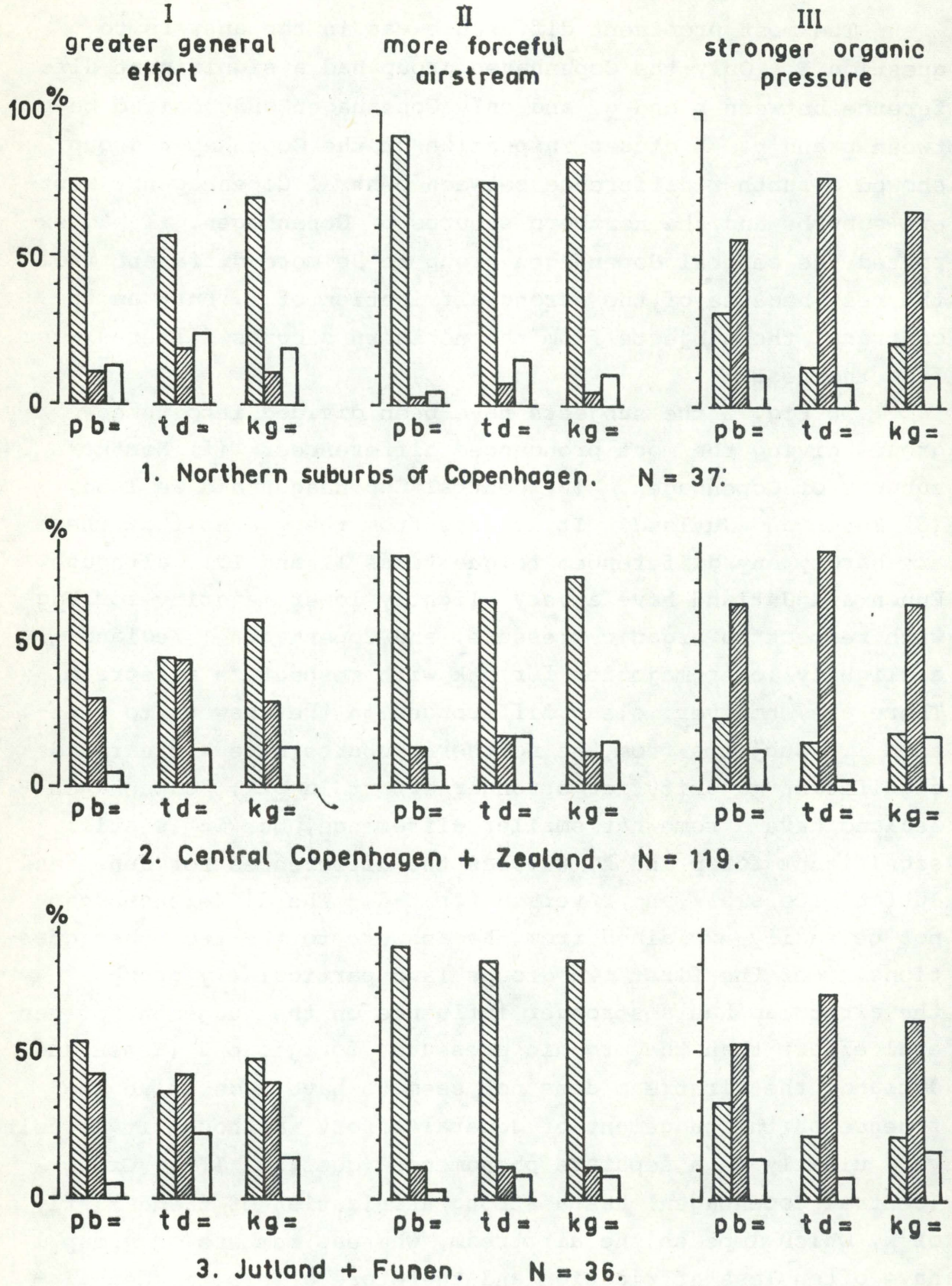

Fig. 2. Answers to the kinesthetic test (in percentage) divided into three geographical groups.

stream, which may have dominated the impression of general effort. The answers of group 1 to the question of overall effort may be taken as a support of the view that this group is characterized by a reaction against the specific features of Copenhagen speech (affrication, and also some features of vowel quality) a view which is contended by some phoneticians. As the consonants of the subjects have not been recorded, this must remain a hypothesis.

4. General discussion

The main result of the experiment with Danish stops, i.e. that most of the subjects consider ptk to require more effort than bdg, and that this answer cannot be explained by any fortis features of the supraglottal cavity, makes it very improbable that Malécot's subjects should have reacted to the activity of the supraglottal cavity only.

The result of the Danish test also gives some support to the traditional designation of ptk as stronger than bdg, not only acoustically, but also kinesthetically, even in cases where they have less energy in the supraglottal cavities.

It is, however, a problem why the stronger airstream is felt as an effort. In question II the subjects were asked to indicate whether they put more force to the airstream in pa than in ba etc. The answer "ptk" can, however, hardly be interpreted to indicate more than the feeling of a stronger airstream. But question 1 was a direct question concerning articulatory effort, and, as demonstrated above, the answers to this question were clearly influenced by the presence of a stronger airstream. Now, if aspiration, as generally assumed, is only due to the fact that the glottis is open during the closure and has not yet been closed at the moment of explosion, then the feeling of effort should be due to laryngeal adjustments. Frøkjær-Jensen-Ludvigsen-Rischel (1971) have brought evidence for the assump-

tion that the slight opening of the glottis in b can be explained by aerodynamic conditions, whereas the large opening in p must require a new neural command. The former is called a "passive opening-closing-gesture", and the latter an "active opening-closing-gesture". According to Rischel (personal communication) the terms "active" and "passive" were meant to imply only that p clearly involves a new neural command, whereas no such assumption seemed necessary for b on the basis of the glottographic material used in the said investigation. A very preliminary processing of some limited electromyographic recordings, made in collaboration with H. Hirose at the Haskins laboratories, does not seem to corroborate the assumption of the passive b-gesture. Both p and b show a clear relaxation of the interarytenoid muscle and an increased activity of the posterior cricoarytenoid, although both phenomena are generally more pronounced and of longer duration in p than in b (this is particularly true of the relaxation of the interarytenoid). The difference between p and b is smaller and the difference between b and the surrounding vowels greater than in the English examples described by Hirose (1970). It is not very probable that this relatively modest difference of activity should be felt as a clear difference in effort. Chomsky-Halle (1968) make the assumption that aspirated stops have heightened subglottal pressure, but I do not know of any physiological evidence for this assumption. As there is hardly any resistance in the glottis, the subglottal pressure must equal the supraglottal pressure in ptk, a pressure which is almost the same as in bdg. It is difficult to see any reason why the pressure below the glottis should be lower in bdg. But it is possible that the simple fact that the speaker loses more breath in syllables with ptk, particularly if they are repeated, is felt as a strain and contributes to the impression of effort. An investigation of respiratory muscles might perhaps throw some light on these problems.

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