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ABSTRACT

It is well known to anyone involved in teaching English to Finnish students that it is difficult for Finns to distinguish between English /ptk/ and /bdg/. This second volume in a series on a Finnish-English contrastive project reports on a study which attempted to obtain more concrete knowledge about the ability of speakers of Finnish to use the various perceptual cues connected with the voiced-voiceless distinction in English. At this initial stage the linguistic material focused on is necessarily very limited and the conclusions arrived at are valid only with reservations. Similarly, only certain aspects are concentrated on. Chapters 2-4 presents the results of the experiment in acoustic terms. The rest of the report is devoted to an attempt to interpret the results of the experiment in the light of articulatory and other physiological evidence. The latter part of the report is necessarily somewhat more speculative in nature. On the bsis of indirect or second-hand evidence, certain inferences about some aspects of the timing of physiological processes are made. Appendices contain a list of test words read by informants and sample mingograms. (Author/AM)

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Reports from
the Department of English
University of Jyväskylä

No 2

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Jyväskylä Contrastive Studies, 2

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by
Kari Suomi

2

Jyväskylä 1976

Reports from the Department of English
University of Jyväskylä

Jyväskylä Contrastive Studies
edited by
Kari Sajavaara and Jaakko Lehtonen



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Reports from
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No 2

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# ENGLISH VOICELESS AND VOICED STOPS AS PRODUCED BY NATIVE AND FINNISH SPEAKERS

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Jyväskylä 1976

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# PREFACE

This study was begun as part of the Jyväskylä Finnish-English Contrastive Project in the autumn of 1974 under the supervision of Jaakko Lehtonen, to whom I am most grateful for the many stimulating discussions I had with him during the planning of the experimental procedures and for the numerous theoretical and practical suggestions which helped me to avoid many errors that would otherwise have been committed. Of course, I am solely responsible for the remaining ones.

I also wish to thank Aritta Göös, Hannele Junni and Sinikka Rouhiainen of the University of Jyväskylä for their invaluable and willing help in solving many practical problems involved. My sincere thanks are also due to my Finnish and English informants.

I do not find it possible to specify in detail the immense influence of Kalevi Wiik's profound scholarship on my phonetic thinking. However, among the more tangible aspects of this teacher-student relation are the many discussions we have had about the theoretical interpretations of the present report, especially those concerning the /fortis/-/lenis/ distinction and the theory of markedness. Kalevi Wiik and Ilkka Raimo, with their wide knowledge of the phonetics of both Finnish and English, have helped me, through many discussions and valuable remarks, to relate the results of the acoustic analysis to the physiological mechanisms governing voicing and aspiration, although it is for me to take full responsibility of any misinterpretations.

The original report, which now appears in a slightly modified version, was presented at the University of Turku as my licentiate thesis in January 1976. Since then, I have received valuable comments and criticism from Pertti Hurme, Antti Iivonen, Jaakko Lehtonen, Michael Pickering, Ilkka Raimo and Kalevi Wiik. However, the present version has not been revised according to these suggestions (which I consider for the most part correct); rather, they will be of great assistance in planning the future directions of the investigation.

I am grateful for the financial support I have received from the University of Jyväskylä and the University of Turku.

Finally I should like to thank Jaakko Lehtonen and Kari Sajavaara for including this study in the Jyväskylä Contrastive Studies, and last, but not least, Aija Saario for typing the manuscript.

Turku, May 1976 K.S.

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# INTRODUCTION

## GENERAL BACKGROUND OF THE STUDY

It is well known to anyone involved in teaching English to Finnish students that it is difficult for Finns to distinguish between English /ptk/ and /bdg/ and that, in addition to minor phonetic mistakes, many phonemic ones occur, both in production and in perception.[1] Phonologically, English /ptk/ and /bdg/ can be described to differ from each other with respect to one (classificatory) feature expressing the "minimal distinction" e.g. /fortis/-/lenis/, /voiceless/-/voiced/, or the like. In contrast, there is phonologically only one full series of stop consonants in Finnish, usually denoted by /ptk/. In addition, there is /d/, the /voiced/ (see for example Wiik 1965: 116, note 7) counterpart of /t/, but with a distribution limited to word medial position only. Thus, considering also the fact that in most dialects of Finnish /d/ is *not* realized as a voiced stop it seems reasonable to assume that a voicing correlation does not exist for speakers of Finnish; rather, the /voiced/ feature of /d/ should probably be regarded as an idiosyncratic property characterizing that segment only.

On the rather abstract level of contrastive phonology, then, the difficulties facing speakers of Finnish (and also their native English listeners) can to a large extent be predicted on the basis of the differences between the sound systems of the two languages. According to the theory of transfer and native language interference, the difficulties of the Finnish speakers are caused by the lack of the corresponding distinctive opposition in Finnish between the two sets of stops. On the phonetic level, however, the relations obtaining within and between the two languages are more complex, and the phonetic features are not always deducible from the phonological ones. Thus in actual speech the opposition between English /ptk/ and /bdg/ is signalled by a combination of several phonetic (articulatory and/or acoustic) parameters, whose relative importance varies according to context. It is conceivable, although not necessarily true, that this makes the task for the Finnish learner even harder as he has to learn a number of contextual allophonic rules (to the extent that they are not universally constrained), rather than a single combination of perceptual

[1] For the terms "phonetic" and "phonemic mistake" see Wiik 1965: 16-17.

cues valid in all environments. Most of the phonetic features used as cues in the English /ptk/-/bdg/ opposition also occur in Finnish, but without any distinctive function. Thus the Finnish stops /ptk/ may be partly or even fully voiced, they may have different degrees of aspiration, frictional noise etc. Some cues, e.g. variations in the durations of sound segments, are used for different purposes in the two languages. In Finnish, (apart from any variations caused by extralinguistic factors such as speech rate etc.) duration is mainly used to signal syntagmatic relations (such as the division of one phonetic segment into one or two phonological ones) and not for segmental information as in English.

To sum up, it seems that ( leaving the marginal Finnish /d/ aside for a moment) the situation corresponds roughly to Wiik's (ibid:20-21) "difference 5 a", a relational difference with sounds contrasting in the target language (i.e. [p-b], [t-d] and [k-g], respectively, in English) but phonetically similar sounds being in free variation in the native (Finnish) language.

This study is an attempt to obtain more concrete knowledge about the ability of speakers of Finnish to use the various perceptual cues connected with the /ptk/-/bdg/ distinction in English. Apart from the rather general and abstract observations of the kind mentioned above such knowledge is as yet mostly lacking. At this initial stage the linguistic material focused on is necessarily very limited and the conclusions arrived at on the basis of the results are valid only with the appropriate reservations. Similarly only certain aspects, i.e. a number of temporal relations obtaining in the productions of English stops by both native and Finnish speakers will be concentrated on. In Chapters II-IV the emphasis is primarily acoustic, and the results of the experiment will be presented in acoustic terms. The rest of the report is devoted to an attempt to interpret the results of the experiment on a higher level in the light of articulatory and other physiological evidence, together with considerations of the predictions of the markedness theory. The latter part of the report is necessarily somewhat more speculative in nature than the acoustic part as the writer has not made any experiments of his own in this area. The interpretations suggested in the latter part are for the most part based on a reconstruction of the results of various experiments found in the literature. On the basis of this kind of indirect or second-hand evidence certain inferences about some aspects of the timing of physiological processes will be made. Most pertinent here seem to be differences in the ability to coordinate supraglottal and laryngeal activities.

## SOME TERMINOLOGICAL CONSIDERATIONS

There is as yet no general agreement about the most important articulatory and/or acoustic correlate of the /ptk/-/bdg/ distinction in English, and consequently various terms have been proposed as the most proper for the (classificatory, phonological) distinctive feature, such as /voiceless/-/voiced/ (the Haskins group),/fortis/-/lenis/ (Gimson 1966), /tense/-/lax/ (Jacobson-Fant-Halle 1955, Chomsky-Halle 1968), /aspirated/-/nonaspirated/ (Erämetsä 1952), etc. The task of finding a descriptively appropriate designation for the phonological distinction is in this case especially difficult as its phonetic manifestations (both physiological and acoustic) differ greatly according to context. Thus, for example, it has been repeatedly argued (see for instance Fischer-Jørgensen 1968: 63) that the terms /voiceless/ and /voiced/ are not particularly felicitous as the /voiced/ sounds are in fact very often phonetically completely voiceless, i.e. produced without any concomitant vocal cord vibration during the occlusion. Similarly, measurements of the various phonetic parameters implied by the other pairs of terms have mostly failed to yield consistent differences between the two sets (see the review of the physiological manifestations of the /ptk/-/bdg/ distinction below).

From a strictly phonological point of view the selection of the name for the distinctive feature is a matter of no consequence as long as the two sets are consistently kept apart by the feature. From a pedagogical point of view, however, e.g. in teaching the language to foreigners, it may be helpful to choose some abstract name for the distinctive feature, a name that somehow succeeds in capturing the speakers' intuition or feeling about the differentiating factor in the distinction, despite the variability of the phonetic output forms that the distinction takes on in actual speech and the variability of the acoustic cues used by the listener in recognizing it. This seems to be essentially the view held for example by Wiik (1965: 36) and Lehtonen (1972: 31-36), who discusses the concept and use of distinctive features at some length.

In agreement with the above considerations, the designations /fortis/ and /lenis/ will be used in this report for /ptk/ and /bdg/, respectively.

However, it must be emphasized that this selection of the terms does not imply any commitment on the part of the writer to any *a priori* view of the phonetic characteristics of the distinction, it merely serves as a way of referring to the two natural classes of sounds. At the same time (and this was the main argument for *not* using the perhaps more usual terms /voiceless/ and /voiced/) a lot of unnecessary but familiar confusion can be avoided by reserving the terms "voiceless" and "voiced" to refer to physical properties of speech sounds, i.e. to the absence or presence of vocal cord vibration during the occlusion and their acoustic equivalents. Where desirable for the sake of clarity, the terms /fortis/ and /lenis/ have also been substituted for others used in the references cited.

# A BRIEF SURVEY OF THE ACOUSTIC AND PERCEPTUAL PROPERTIES OF THE FORTIS/LENIS DISTINCTION

## THE OUTLINE OF THE SURVEY

In this survey of the results obtained in the study of the acoustic and perceptual characteristics of the English /fortis/-/lenis/ distinction it is possible to mention only a few of the most important studies. For more detailed information, especially about the pioneering analysis-by-synthesis work of the Haskins group, the reader is advised to the various published reviews and the references therein (see for example Liberman, Ingemann, Lisker, Delattre and Cooper 1959; Liberman, Cooper, Shankweiler and Studdert-Kennedy 1967; Stevens and House 1971; Liberman and Cooper 1972). As the present study is mainly concerned with the differences between the cognate pairs of the English stops (i.e. with the factors that differentiate the series /ptk/ from the series /bdg/) differences due to place of articulation are dealt with only to the extent that they are assumed to be connected with the /fortis/-/lenis/ distinction. In connection with the discussion of the results of this study some more general aspects of place of articulation will be discussed. This delimitation of the subject matter is motivated by the fact that speakers of Finnish have generally no difficulties in recognizing English /p/ and /b/ as labial stops, /t/ and /d/ as alveolar stops etc., i.e., they do not usually make "place" mistakes either in perception or in production.

The account given by Gimson (1966: 144-62) has been chosen as a starting point in this brief survey mainly for two reasons. Firstly, Gimson's book is widely used at Finnish universities and most students of English are familiar with it. The second reason is the fact that it is one of the few systematic accounts of the acoustic properties of the English stops; most articles and reports are quite naturally concerned with some specific aspect of /fortis/-/lenis/ distinction only. The significant phonetic features mentioned by Gimson will be presented, following his tripartite division (word initial, medial and final positions), together with a sketch of the results of some important analytical and/ or perceptual studies. It may be pointed out that most of the experiments discussed deal with American English whereas Gimson describes British English. However, it is assumed here that the possible differences between the two forms of English are not so great as to render this type of treatment unjustifiable. In support of this view it can be mentioned that Gimson is referring to the same or similar studies.

THE WORD INITIAL POSITION

It may be noted in passing that the necessary distinction between word initial and utterance initial positions has not always been consistently maintained. Gimson, however, refers specifically to word initial position.

According to Gimson (1966: 149), /ptk/ may in any position be distinguished from /bdg/ acoustically by means of a low frequency component in the latter, i.e. voice. Another cue supposedly equally capable of signalling the distinction in all positions is the more marked rising bend of the first formant (F1) of the adjacent vowel in the case of /bdg/. However, noting that /bdg/ may often be completely voiceless, Gimson states that in these cases they are distinguished from /ptk/ initially by the comparatively weak burst of noice associated with the release stage and by the absence of aspiration that characterizes the latter series.

Lisker (1957: 42) states that in word initial position aspiration is the most prominent cue for the /fortis/ series (it may well deserve to be mentioned here that Lisker has repeatedly refused to accept the terms "fortis" and "lenis", instead he insists on the use of the terms "voiceless" and "voiced"). Similarly in Delattre's (1964) list aspiration is ranked as the strongest cue in initial position. Later Lisker and Abramson have studied the voice onset time or VOT of word initial stops in a number of languages (Lisker and Abramson 1964; 1970; Abramson and Lisker 1970; 1972; 1973). The VOT is defined (Lisker and Abramson 1964: 422) in spectrographic terms as the time interval between the burst that marks the release of the stop and the onset of periodicity that reflects laryngeal vibration. In the case of a voicing lead (i.e. when periodicity begins before the release) the VOT assumes a negative value (e.g. in milliseconds), and in the case of a voicing lag (periodicity begins only some time after the burst that marks the release) it assumes a positive value. Lisker and Abramson's main results include the observation that in English (and many other languages with two or more series of stops) the stop categories occupy distinct ranges along the VOT continuum, both in production and in perception, with both /ptk/ and /bdg/ normally having a voicing lag, but longer for /ptk/.

The burst mentioned by Gimson has also been the subject matter of several studies. Halle, Hughes and Radley (1957) made the observation that the "intensity bursts" for /ptk/ were higher than those for /bdg/ in word initial position. According to Delattre (1964) the intensity of the noise is among the weakest of the seven factors (=cues) for /fortisness/ that he has posited. However, we are not told whether this is a peculiar feature of the word initial position only or whether it is applicable to the other positions as well.

It may be mentioned here that in the classical Haskins terminology "burst" often included both the fricative noise signalling the release and the aspiration due to a lag in the onset of vibration, and in this sense it can be equated with a positive VOT value.

Recently Stevens and Klatt (1974) have reinvestigated the acoustic cues for the /fortis/-/lenis/ distinction in prestressed English stops. They suggest that instead of an absolute VOT value the presence or absence of a rapid spectrum change at voice onset might be the primary cue that the listener uses in distinguishing between /ptk/ and /bdg/. It is a commonplace that in heavily aspirated stops the formant transitions are virtually completed before the onset of voicing, whereas in unaspirated or slightly aspirated stops these changes occur during voicing. This cue seems to be applicable mainly in word initial and/or prestressed positions where the aspiration of the /fortes/ is usually rather extensive.

It has been known for some time that the /fortis/-/lenis/ character of a stop has an effect on the initial pitch of the following vowel (see for example House and Fairbanks 1953). Haggard, Ambler and Callow (1970) have studied the cue value of this phenomenon in word initial position and they report that for the majority of their subjects the pitch change in the vowel can cue the /fortis/-/lenis/ distinction for a preceding stop consonant.

THE WORD MEDIAL POSITION

Medially, following an accented syllable the two series of stops are according to Gimson distinguished by the longer closure period (absence of energy) required for /ptk/ and by a weak aspiration in /ptk/ as against lack of aspiration in /bdg/. The /lenis/ series is normally voiced in this position.

Lisker (1957) offers experimental evidence to support the view that differences in closure duration play a major role in the /fortis/-/lenis/ stop distinction in word medial, intervocalic position. His results are based on tape-splicing experiments with real-speech stimuli and they indicate that a longer closure duration is predominantly connected with the /fortis/ series in perception. Similar results were obtained (through analysis) in a recent investigation by Suen and Beddoes (1974), who conclude that the duration of the silent interval is an important factor in the perception and discrimination of the /fortis/-/lenis/ distinction in word medial (and final) position. However, it is worth emphasizing in this connection that the authors do not deal with the two positions separately; instead, the data for them are pooled together. Delattre (1964) says that the duration of silence has "medium power of discrimination", and in the Haskins rules for synthesizing English a longer silent interval was connected with /ptk/ (Liberman, Ingeman, Lisker, Delattre and Cooper 1959). It is interesting in this connection to note that Lisker, in a later article (1972), argues on the basis of his measurements that a difference in closure duration is far from being a regular feature of the /ptk/-/bdg/ contrast in English. Thus we see again that there seems to be no conclusive evidence of the importance of differences in closure duration. On the whole it is remarkable that the medial position has drawn very little attention compared to the initial and final positions.

THE WORD FINAL POSITION

Gimson states that word finally /ptk/ are distinguished from /bdg/ either by a reduction of the duration of the sounds preceding the /fortis/ series or by the presence of some voicing in the /lenis/ stops, or by a combination of both factors.

There are few, if in fact any, areas in the phonetics of English that have stimulated more reseach than the /ptk/-/bdg/ distinction, and perhaps the majority of these studies have focused their attention to the word final position. Consequently the effect of the /fortis/-/lenis/ character of the final consonant on the duration of the preceding vowel is well documented in the literature (e.g. House and Fairbanks 1953; Zimmerman and Sapon 1958; Peterson and Lehiste 1960; Wiik 1965; Chen 1970). In all studies it has been noticed that sonorants have a longer duration before /lenes/ than before /fortes/. A great number of perceptual experiments have been undertaken, mostly with synthetically produced stimuli. Denes (1955) found that the relative durations of a word final consonant and the preceding vowel can be used as a cue for identifying the final sound as /fortis/ or /lenis/, even in the absence of any actual voicing during the consonant. In Denes' experiment the final consonant was a fricative but later it has been amply demonstrated that the same conclusions are valid for final stops as well. Delattre (1964) mentions the longer duration of a preceding vowel as a cue for /bdg/. More recently Raphael (1972) has come to the conclusion that preceding vowel duration is a sufficient (and for the types of stimuli used in his experiments, a necessary) cue to the perception of the /fortis/-/lenis/ character of a word final stop, fricative or consonant cluster. He further concludes that the presence of voicing during the closure period of a final consonant or cluster does have some cue value, although it is minor compared to that of the preceding vowel duration.

One of the reasons why the word final stops in English have attracted the attention of so many linguists and phoneticians is no doubt the fact that it is a clear example of a situation where one segment is identified on the basis of the acoustic properties of another. However, such a situation is by no means unique.

A similar relationship between word (or syllable) final consonants and preceding vowels has been observed for a variety of languages, and it is more than likely that at least part of the durational variation is conditioned by some kind of a universal articulatory constraint. For analytical data in support of such view see for example Zimmerman and Sapon (1958) for Spanish, Fintoft (1962) for Norwegian, Wiik (1965) for Finnish (in Wiik's /voiced/ category only one true obstruent is included, viz. /d/), Chen (1970) for French, Russian and Korean. It seems, however, that the prolongation of sonorants before a /lenis/ consonant is much more drastic in English than in the other languages, and accordingly it is most likely that this extra lengthening is a language specific feature of English (see especially Chen 1970).

It is noteworthy that apart from the observation made by Suen and Beddoes (1974) to the effect that closure duration is an important discriminating factor even in final position, no other references to the possible role of durational differences in the silent interval of word final stops could be found in the literature. Experimental data on the cue value of such differences exist, however, for Norwegian (Fintoft and Selnes 1971) and French (Wajskkop and Sweerts 1973).

# THE PROCEDURE OF THE INVESTIGATION

## THE SELECTION OF INFORMANTS

The criteria used in the selection of the informants of this study were to a large extent determined on the basis of the general outlines of the project of which this investigation is a part. Thus it was decided that three groups of informants would be used, one consisting of native (British) English speakers, the other two groups representing two levels of Finnish speakers with different degrees of familiarity with the English language. It would have been desirable to have the first group dialectally as homogeneous as possible, to enable concentration on merely inter-language differences. For quite practical reasons, however, this could not be achieved as a further restriction was imposed to the effect that only male informants would be used, with a view to possible later spectral analysis of the material. Given these restrictions and the need of five informants there was not very much choice in the town of Jyväskylä. However, it is trusted that the dialectal differences existing among the native English group (hereafter group *Engl.*) are not so great as to affect the results of this study to any appreciable degree.

With regard to the Finnish informants the dialectal background was not considered important as the informants do not speak their native language in the utterances under investigation. This does not, of course, exclude the possibility that native language dialect could in some instances leave clearly identifiable traces on the pronunciation of a foreign language. Here, however, there seems to be no reason to believe that such effects are operative.

Instead of dialectal background the degree of familiarity with the English language was chosen as the variable to obtain two groups of Finnish informants. It was decided that the first group, referred to below as *S1.*, would consist of five male informants with the following history with regard to English: a secondary school course (7 or 3 years) in the language, with no later studies at a university or elsewhere. It was also checked that the informants had had no further practical experience with spoken English (to the extent that this is possible), and with a certain amount of reservation the group could be thought to represent the kind of competence in English that the Finnish secondary school can offer. One of the reservations is that some of the informants may have forgotten some of their English while others may have improved with the help of English films, records etc. However, testing such variables would have necessitated arrangements completely different from the ones used in the present study. In fact all the informants belonging to group *S1*. are students of mathematical subjects at the University of Jyväskylä, with some experience in reading professional textbooks in English but no experience with the spoken language. Nor had they had any experience with other foreign languages since school.

The second group of Finnish informants, referred to below as *S2*., was selected on the following criteria: completed *cum laude* course in English (philology) at the university, male and availability on the campus. No further restrictions were made and the group *S2*., again with a certain amount of reservation, could be considered as representative of the level achieved by most future teachers of English. Certain pedagogical relations obtain between the three groups:[1] At a given moment, the group *Engl*. teach and give the pronunciation model to the group *S2*. who later teach and give the pronunciation model to members of the group *S1*. Thus the model given to the latter group is one stage removed from the original, and an individual student of English does not receive the authentic model until at a rather late stage of his/her learning process. This is not of course in all respects the happiest possible situation, although it must be admitted that many other circumstances must be considered in planning effective foreign language teaching.

## THE SELECTION AND READING OF THE TEST MATERIAL

The subject matter of this report, the English stops, is very extensive and only some of their many aspects can be dealt with in a single study. Therefore severe restrictions on the selection of the linguistic material have been necessary to enable more systematic concentration on some of these aspects, in this case certain temporal relations obtaining in the production of these sounds by native and Finnish speakers, as re-

[1] This observation the present writer owes to Mr. Jean-Yves Paré of the University of Jyväskylä.

vealed by or deducible from the kind of acoustic analysis used here. It would of course be ideal to study the production of these sounds in completely natural, spontaneous speech. For practical reasons, however, many compromises must be made. For example, it must be decided whether the sounds to be studied should occur in a sentence context or in separate words. The former alternative would perhaps be theoretically more interesting but unfeasible in practice as it is normally demanded that speech sounds should be investigated in the most identical environments. The elimination of all semantic, sentence phonetic and other such variables would enlarge the scope of the material under investigation to unmanageable proportions.

In this experiment the following arrangement was used: the test words (altogether 117 in number, see Appendix A) containing the sounds to be analyzed are each printed on its own card, as the middle one in the sequence of three words. Thus there were 117 cards, each card containing a "sentence" of three English words, with the word to be studied as the middle one. The words on a card do not form a semantically coherent sentence; instead, the three-word combinations are nonsense. However, the informants were instructed to read the words on each card in a sentence manner, i.e. as one breath group, yet with clear pauses between the words. Using this technique it is possible better to control the effect of the variables referred to above and yet avoid the use of completely artificial nonsense words. For example, it is known that the use of a frame sentence, when repeated over and over, can create a rhythmic way of reading which can very severely distort the natural temporal relations between sound segments. Similarly it is known that words produced in complete isolation are usually subject to great temporal modifications. The decision to have the crucial word to occur in the middle of two other, variable words was made on the basis of a desire to exclude the effects of higher syntactic boundaries on the sounds, such as the notorious "final lengthening" affecting the last syllable of a sentence. At the same time any rhythmic patterns could be avoided.

The subject matter of the present investigation was further delimited in such a way that the stops were studied only in a position adjacent to a vowel with primary lexical stress, with the exclusion of consonant clusters. The word structures under investigation are *CVC* and *CV́CV*, where *C* is one of /ptkbdg/ and the stressed vowel *V́* belongs to one of the groups

/tense/, /lax/ or /ae/. With this arrangement it is possible to compare the effects of the stops on the durations of the different vowel categories. As the vowels are not the actual subject matter of the study no further division of the vowel classes was regarded necessary. Thus it is possible to study the stops in word initial, medial and final positions, with a stressed vowel following (in the case of initial stops) or preceding the stop.

## THE ANALYSIS PROCEDURES

*The equipment and the segmentation techniques.* – The speech material was recorded in the studio of the Phonetics Laboratory of the University of Jyväskylä, using an Altec 29 A condenser microphone and a Revox A 77 tape recorder. The recording speed was 19 cm per second.

The test tapes were analyzed by an ink-writer to which Frøkjaer-Jensen's Trans-Pitchmeter and Intensity Meter had been attached. With this apparatus three curves were obtained, namely the "duplex oscillogram", an intensity curve with high-pass filtering at 500 cps, plus another intensity curve with low-pass filtering at 500 cps (for a more detailed account of the technical characteristics and use of these curves see for example Hadding-Petersson 1970: 93-97, and Lehtonen 1970: 46-47). The paper speed used in the Mingograph was 100 mm per second, thus giving 1 mm = 1/100 sec. or 1 csec. Measurements were made to the nearest 0,5 mm, representing 5 msec. on the time scale. The time constant used for the two intensity curves was 10 msec., which gives an indeterminacy in the time domain of approximately corresponding size. Whenever possible the actual segment boundaries were specified on the basis of the "duplex oscillogram" whose time determinacy is more accurate.

*The test parameters.* – On the basis of the above three recordings the following parameters could be measured, all expressing temporal distances between acoustic events: the extent of voicing (EV) and release duration (RD) of word initial stops (plus their combination, the voice onset time or VOT); the duration of the stressed vowel (VD), the silent interval (SI);

EV and RD of word medial stops; and the SI and EV of word final stops. It is well known that it is not possible to determine the duration of the silent interval of a word initial stop preceded by silence (if only acoustic information is available), and therefore only the parameters EV and RD (the latter being a measure of the temporal distance between the first burst of noise signalling the release of the oral closure and the onset of periodic vibration signalling the beginning of the vowel segment) have been measured. The measurement of the VD, SI, EV and RD in connection with the medial stops was quite straightforward, but it turned out that the end of the second (word final) vowel in the two-syllable words and the duration of the release of the word final stops could not be determined with sufficient accuracy, and consequently they had to be left out of consideration. In contrast the ends of the silent intervals of the word final stops were always visible on the curves enabling the SI of these consonants to be measured. This happened in spite of the fact that the informants were in no way asked to release their final stops. For examples of the segmentations made see the sample mingograms in Appendix B.

*The statistical analysis.* – The arithmetic means ($\bar{X}$) and standard deviations (s) given have been calculated for each group, but not for the individual members of the groups. Thus the means and deviations of each group have not been calculated from the means of the members in each group but from the original individual data. This means that any possible between-subject differences within a group have been purposedly neglected and each group is treated as if it were essentially homogeneous.

There are differences in the overall rate of speech between speakers, and these differences naturally cause differences in the durations of individual sound segments. In a study of temporal relations such essentially random variations could have drastic effects on the form of the results. Thus, in a hypothetical example where the average durations of sound segments A, B and C are, say, 6, 18 and 12 csec., respectively, for one group, and the respective durations for another group are 4, 12 and 8 csec., it is possible that a straightforward statistical comparison would yield highly significant differences between the groups with respect to each of the three sound segments, despite the fact that the interrelations between the segments are in fact the same in both groups, i.e. the ratio between the durations of the segments is 1:3:2. If instead of the sketched procedure the sound segments were compared to each other *within* the groups, it would be noticed that both groups express the linguistic relations in the same way, i.e. the sound segments A, B and C differ from each other in an analoguous fashion. A method similar to the latter one has been adopted in the statistical analysis of this study also because there is no *a priori* reason for believing that linguistic rules affecting the duration of sound segments work on a relative rather than an absolute basis, and thus any kind of normalization of the data (such as using the so-called z-points) might distort important patterns in them. Accordingly durational differences due to different linguistic categories have been compared and tested for significance by the *t*-test within each of the three groups. In this way most of the artefacts resulting from inter-individual differences have been prevented from showing in the statistical analyses. So for instance it has not been possible with this arrangement to test the significance of the differences in the duration of word medial stops between the three groups *Engl.*, *S2.* and *S1.* Instead, it is possible (and it has been considered more relevant) to test, within each group, the significance of the differences between linguistically distinctive categories, in this case such as /fortis/-/lenis/ or /place of articulation/.[1]

[1] The significance of the differences between means is indicated in the following way: one asterisk (*) = almost significant ($p < 5\%$), two asterisks (**) = significant ($p < 2\%$), three and four asterisks = strongly significant (*** = $p < 1\%$; **** = $p < 0,5\%$). Lower levels of significance have been disregarded. I want to express my thanks to Messrs Alvar Koppinen at the Institute for Educational Research and Kauko Saarinen at the Computer Centre of the University of Jyväskylä for their kind help in planning and performing, respectively, the statistical analyses of this study.

# THE RESULTS

## THE PRESENTATION OF THE DATA

In the Tables and Charts below the effects of different phonological variables or classificatory features on the temporal relations of the phonetic segments have been tabulated together with an indication of the differences of the means and their significance, as specified by the *t*-test. Only those phonetic segments or parameters have been tabulated under the respective distinctive oppositions whose duration has at least for one of the groups been significantly influenced by the opposition. Thus for example the release duration or RD of a word medial stop has not been affected by the /fortis/-/lenis/ distinction of the word initial stops, and accordingly it has not been tabulated under the word initial /fortis/-/lenis/ distinction, etc.

## THE WORD INITIAL POSITION

*The /fortis/-/lenis/ distinction.* — Tables 1-3 present the data on the acoustic segments influenced by the word initial /fortis/-/lenis/ distinction for the groups *Engl.*, *S2.* and *S1.*, respectively. In Table 4 the differences of means for each group have been tabulated to enable comparison between the groups, although, as was explained above, it has not been possible to ascertain the significance of the between-group differences of means. In Tables 1-4 the results for the two categories have been pooled across the three places of production (labial, alveolar and velar) to render a general view of the effect of the /fortis/-/lenis/ distinction on the duration of the phonetic segments studied here. There were no significant differences in the means of any of the parameters between words of one or two syllables.

From the Tables it can be seen that all three groups have strongly significant differences in the means of all parameters (except for group *S1.* who have a merely significant difference in the duration of the following stressed vowel), although there are differences in the absolute msec. figures between the groups. However, a closer examination of the

Tables 1-4. The effect of the word initial /fortis/-/lenis/ distinction on the parameters EV (extent of voicing), RD (release duration), VOT (voice onset time of the initial stop) and VD (duration of the following vowel). The units are milliseconds.

Table 1. Group *Engl.*

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_f-\bar{X}_l$ | P |
| EV | 0 | 0 | 325 | 58 | 59 | 260 | -58 | **** |
| RD | 59 | 17 | 325 | 11 | 9 | 260 | 48 | **** |
| VOT | 59 | 17 | 325 | -51 | 66 | 260 | 110 | **** |
| VD | 144 | 67 | 325 | 184 | 77 | 260 | -40 | **** |

Table 2. Group *S2.*

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_f-\bar{X}_l$ | P |
| EV | 1 | 10 | 325 | 79 | 38 | 260 | -78 | **** |
| RD | 63 | 28 | 325 | 8 | 13 | 260 | 55 | **** |
| VOT | 62 | 30 | 325 | -76 | 44 | 260 | 138 | **** |
| VD | 154 | 64 | 325 | 173 | 65 | 260 | -19 | **** |

Table 3. Group *S1.*

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_f-\bar{X}_l$ | P |
| EV | 2 | 15 | 325 | 34 | 44 | 260 | -32 | **** |
| RD | 34 | 22 | 325 | 14 | 18 | 260 | 20 | **** |
| VOT | 34 | 24 | 325 | -20 | 55 | 260 | 54 | **** |
| VD | 126 | 54 | 325 | 138 | 59 | 260 | -12 | ** |

Table 4. Comparison of the groups.

| | $\bar{X}_f-\bar{X}_l$ | | | P | | |
|---|---|---|---|---|---|---|
| | *Engl.* | *S2.* | *S1.* | *Engl.* | *S2.* | *S1.* |
| EV | -58 | -78 | -32 | **** | **** | **** |
| RD | 48 | 55 | 20 | **** | **** | **** |
| VOT | 110 | 138 | 54 | **** | **** | **** |
| VD | -40 | -19 | -12 | **** | **** | ** |

results revealed that there are consistent differences between the three places of production, and therefore it is more revealing to discuss the /fortis/-/lenis/ difference with the data for each place of articulation separated. Tables 5-7 show the data for the labial, Tables 8-10 for the alveolar and Tables 11-13 for the velar stops. In Tables 14-16 the differences in means of the three places of production and their significance have been tabulated for each group to enable direct comparison of the English and the Finnish groups.

In each group and through all places of articulation there are strongly significant differences between the two categories /fortis/ and /lenis/ with respect to initial voicing. As could be expected, voicing is throughout more extensive in the /lenes/. It will be noticed that through all three places of production group *Engl.* has more extensive voicing of the /lenes/ than group *S1*. This, too, could be expected on the basis of purely phonological considerations. The behaviour of group *S2*. (the more advanced Finnish group), on the contrary, does not follow the expected pattern of assuming an intermediate position between the two other groups; instead, the group seems to have "overshot" the target model displayed by group *Engl.* (this observation has no counterexamples; in each place of articulation the /lenes/ of group *S2*. have the longest and those of group *S1*. the shortest extent of voicing). This is probably a reflection of the fact that /bdg/ are usually called *voiced* stops in a rather categorical way in many Finnish textbook of English. It will be seen below that this is not the only instance where group *S2*. shows this kind of exaggeration.

Another remarkable thing about voicing is the fact that both groups of Finnish informants show some instances of voicing of the /fortes/ while those of the English group are without exception completely voiceless. This is doubtless a reflection of the fact that phonologically voicing is irrelevant in Finnish, whereas in English this phonetic dimension contributes its own share in keeping the two categories distinct.

With regard to RD or release duration group *S2*. again takes an extreme position in the labial (55 msec.) and velar (65 msec.) stops, in the alveolars the group has an intermediate position. It can be seen that although the differences of the RD means between the two categories are strongly significant for each group the separation of the categories is only of the order of about 2 csec. for group *S1*. (Tables 7, 10 and 13), Tables 5-7. The effect of the word initial /fortis/-/lenis/ distinction on the labial stops.

Table 5. Group *Engl.*

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_f$-$\bar{X}_l$ | P |
| EV | 0 | 0 | 100 | 65 | 61 | 95 | -65 | **** |
| RD | 50 | 15 | 100 | 7 | 10 | 95 | 43 | **** |
| VOT | 50 | 15 | 100 | -61 | 66 | 95 | 111 | **** |
| VD | 146 | 64 | 100 | 179 | 76 | 95 | -33 | **** |

Table 6. Group *S2*.

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_f$-$\bar{X}_l$ | P |
| EV | 2 | 16 | 100 | 92 | 32 | 95 | -90 | **** |
| RD | 56 | 29 | 100 | 1 | 3 | 95 | 55 | **** |
| VOT | 54 | 36 | 100 | -92 | 33 | 95 | 146 | **** |
| VD | 158 | 64 | 100 | 172 | 62 | 95 | -14 | non |

Table 7. Group *S1*.

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_f$-$\bar{X}_l$ | P |
| EV | 4 | 17 | 100 | 37 | 49 | 95 | -33 | **** |
| RD | 24 | 22 | 100 | 7 | 12 | 95 | 17 | **** |
| VOT | 21 | 26 | 100 | -30 | 55 | 95 | 51 | **** |
| VD | actual data lost, see the text | | | | | | | non |

and there is certainly extensive overlapping of the categories. This is specifically indicated by the large standard deviations (s) of the /lenes/ of the group.

The VOT is essentially a combination of the two previous parameters, and accordingly it shows their joint effect. The VOT values are represented

Tables 8-10. The effect of the word initial /fortis/-/lenis/ distinction on the alveolar stops.

Table 8. Group *Engl.*

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_f$-$\bar{X}_l$ | P |
| EV | 0 | 0 | 115 | 53 | 56 | 95 | -53 | **** |
| RD | 61 | 16 | 115 | 11 | 7 | 95 | 50 | **** |
| VOT | 61 | 16 | 115 | -46 | 63 | 95 | 107 | **** |
| VD | 147 | 68 | 115 | 176 | 78 | 95 | -29 | **** |

Table 9. Group *S2*.

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_f$-$\bar{X}_l$ | P |
| EV | 1 | 8 | 115 | 67 | 40 | 95 | -66 | **** |
| RD | 52 | 19 | 115 | 12 | 17 | 95 | 40 | **** |
| VOT | 52 | 19 | 115 | -60 | 52 | 95 | 112 | **** |
| VD | 157 | 65 | 115 | 160 | 66 | 95 | -3 | non |

Table 10. Group *S1*.

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_f$-$\bar{X}_l$ | P |
| EV | 2 | 13 | 115 | 32 | 40 | 95 | -30 | **** |
| RD | 31 | 18 | 115 | 10 | 10 | 95 | 21 | **** |
| VOT | 31 | 18 | 115 | -21 | 46 | 95 | 52 | **** |
| VD | actual data lost, see the text | | | | | | | non |

diagrammatically in Chart 1. It is at once apparent from the diagram that the separation of the two categories is best for group *S2*. and poorest for group *S1*. It is also obvious that the VOT values are greatly dependent on the place of production of the stops. This point will be discussed below (pp. 25ff.).

Tables 11-13. The effect of the word initial /fortis/-/lenis/ distinction on the velar stops.

Table 11. Group *Engl.*

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_f$-$\bar{X}_l$ | P |
| EV | 0 | 0 | 110 | 56 | 61 | 70 | -56 | **** |
| RD | 65 | 16 | 110 | 18 | 8 | 70 | 47 | **** |
| VOT | 65 | 16 | 110 | -47 | 70 | 70 | 112 | **** |
| VD | 142 | 70 | 110 | 201 | 77 | 70 | -59 | **** |

Table 12. Group *S2.*

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_f$-$\bar{X}_l$ | P |
| EV | 0 | 0 | 110 | 77 | 36 | 70 | -77 | **** |
| RD | 79 | 26 | 110 | 14 | 11 | 70 | 65 | **** |
| VOT | 79 | 26 | 110 | -76 | 39 | 70 | 155 | **** |
| VD | 147 | 62 | 110 | 194 | 65 | 70 | -47 | **** |

Table 13. Group *S1.*

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_f$-$\bar{X}_l$ | P |
| EV | 2 | 13 | 110 | 31 | 43 | 70 | -29 | **** |
| RD | 48 | 21 | 110 | 30 | 23 | 70 | 18 | **** |
| VOT | 48 | 21 | 110 | -4 | 61 | 70 | 52 | **** |
| VD | actual data lost, see the text | | | | | | | non |

For group *Engl.* the difference between vowel durations after /fortis/ and /lenis/ stops is strongly significant for each place of production. The duration of the stressed vowels in the present study has been measured from the instant that voicing begins after initial aspiration in voiceless stops or from the instant of a sudden rise in intensity indicating the re-

Tables 14-16. Summary of the effect of the word initial /fortis/-/lenis/ distinction on the stops of different place of articulation.

Table 14. The labial stops.

| | $\overline{X}_f-\overline{X}_l$ | | | P | | |
|---|---|---|---|---|---|---|
| | *Engl.* | *S2.* | *S1.* | *Engl.* | *S2.* | *S1.* |
| EV | -65 | -90 | -33 | **** | **** | **** |
| RD | 43 | 55 | 17 | **** | **** | **** |
| VOT | 111 | 146 | 51 | **** | **** | **** |
| VD | -33 | -14 | ?? | **** | non | non |

Table 15. The alveolar stops.

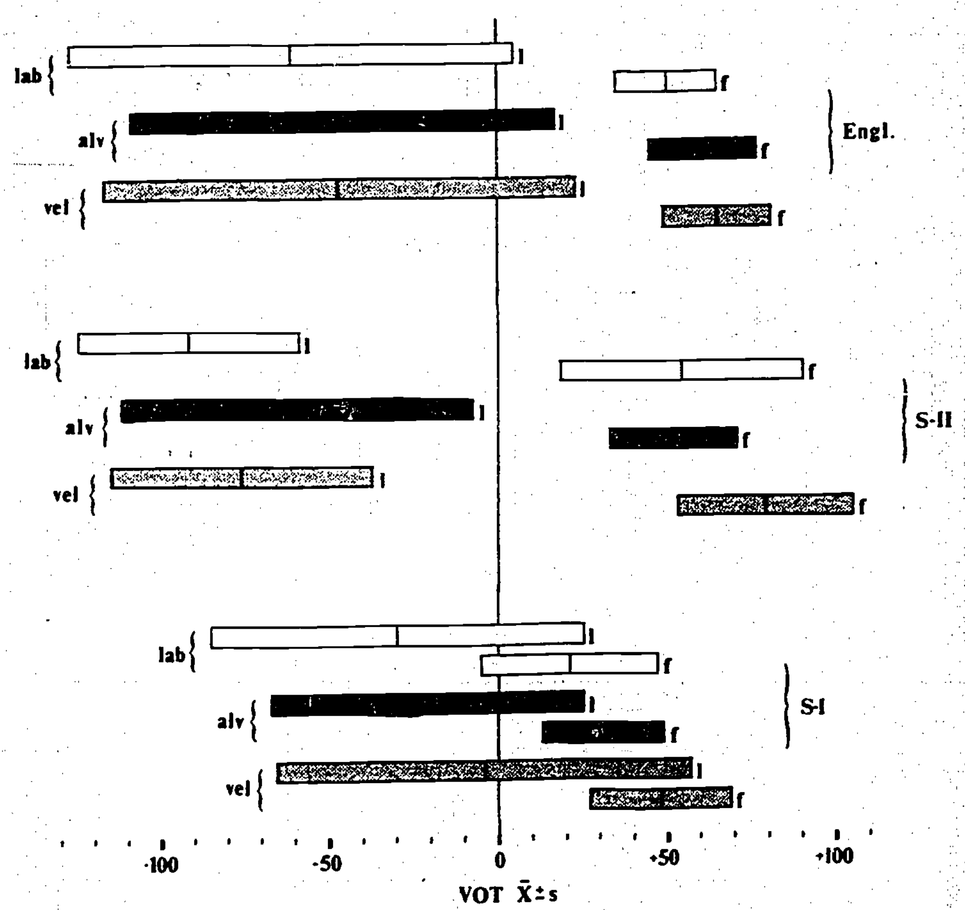
| | $\overline{X}_f-\overline{X}_l$ | | | P | | |
|---|---|---|---|---|---|---|
| | *Engl.* | *S2.* | *S1.* | *Engl.* | *S2.* | *S1.* |
| EV | -53 | -66 | -30 | **** | **** | **** |
| RD | 50 | 40 | 21 | **** | **** | **** |
| VOT | 107 | 112 | 52 | **** | **** | **** |
| VD | -29 | -3 | ?? | **** | non | non |

Table 16. The velar stops.

| | $\overline{X}_f-\overline{X}_l$ | | | P | | |
|---|---|---|---|---|---|---|
| | *Engl.* | *S2.* | *S1.* | *Engl.* | *S2.* | *S1.* |
| EV | -56 | -77 | -29 | **** | **** | **** |
| RD | 47 | 65 | 18 | **** | **** | **** |
| VOT | 112 | 155 | 52 | **** | **** | **** |
| VD | -59 | -47 | ?? | **** | **** | non |

lease of the occlusion in the case of voiced stops, a method which naturally shortens vowels after strongly aspirated stops. Wiik (1965), for instance, has included the release segment in the duration of the vowel

CHART 1. The VOT values ($\bar{X} \pm s$) of the word initial stops for the three groups. The units on the time scale are milliseconds, 0 indicating the moment the oral closure is opened, *f* and *ℓ* stand for the categories /fortis/ and /lenis/, respectively.



with which arrangement the duration of the vowel is the same after stops of both categories. In fact it can be seen in the present data (Tables 5, 8 and 11) that the differences in the release and vowel durations approximately compensate each other. Among the Finnish groups only the velars of group *S2.* (Table 12) show a significant difference comparable to those of group *Engl.* This means that for the labials and alveolars group *S2.* have lengthened the duration of the oral opening in order to achieve equal durations of vowels after both /fortes/ and /lenes/. Due to an accident the actual numerical data on the vowel durations of group *S1.* in Tables 7, 10 and 13 were lost after it had been assessed that the differences in their means were not statistically significant.

*The effect of the place of production.* — To facilitate the evaluation of the effect of the place of articulation on the parameters the data have been reorganized in Tables 17-22. Tables 17-19 show the word initial /fortes/ and Tables 20-22 the /lenes/.

It is clear from these Tables that the observed differences of VOT between the places of articulation depend mostly on differences in the release duration or RD and not on any significant differences in the extent of initial voicing or EV. Only group *S2.* exhibits (see Table 21) any significant differences between the places of articulation with regard to voicing in that /b/ has a slightly longer extent of voicing than /d/ and /g/. It seems futile to try to explain this, although it might not be impossible to think of an aerodynamic explanation (/b/ having the largest cavity between the glottis and the place of the occlusion, a state of affairs making possible a prolonged transglottal flow of air necessary for voicing).

With regard to the release duration or RD there is a clear tendency in both series (i.e. in both the /fortes/ and the /lenes/) and all groups for a longer release duration with increasing retraction of the place of production. Thus the velars have the longest and the labials the shortest release durations, while the alveolars have a medium one. It is worth pointing out that there are no statistically significant exceptions to the above tendency in the present data, a fact that would seem to indicate a physiological or other universal origin for the observed differences. To such a direction points also the fact that similar results have been obtained for a number of languages, see for example Lisker and Abramson (1964). As the

Tables 17-19. The effect of the place features /labial/, /alveolar/ and /velar/ on the parameters EV, RD and VOT of the word initial /fortes/.

Table 17. Group *Engl.*

| | /labials/ | | | /alveolars/ | | | /velars/ | | | differences of means | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_1$ | $s_1$ | $N_1$ | $\bar{X}_a$ | $s_a$ | $N_a$ | $\bar{X}_v$ | $s_v$ | $N_v$ | $\bar{X}_1-\bar{X}_a$ | $\bar{X}_1-\bar{X}_v$ | $\bar{X}_a-\bar{X}_v$ | $P_{1-a}$ | $P_{1-v}$ | $P_{a-v}$ |
| EV | 0 | 0 | 100 | 0 | 0 | 115 | 0 | 0 | 110 | 0 | 0 | 0 | non | non | non |
| RD | 50. | 15 | 100 | 61 | 16 | 115 | 65 | 16 | 110 | -11 | -15 | -4 | **** | **** | * |
| VOT | 50 | 15 | 100 | 61 | 16 | 115 | 65 | 16 | 110 | -11 | -15 | -4 | **** | **** | * |

Table 18. Group *S2.*

| | /labials/ | | | /alveolars/ | | | /velars/ | | | differences of means | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_1$ | $s_1$ | $N_1$ | $\bar{X}_a$ | $s_a$ | $N_a$ | $\bar{X}_v$ | $s_v$ | $N_v$ | $\bar{X}_1-\bar{X}_a$ | $\bar{X}_1-\bar{X}_v$ | $\bar{X}_a-\bar{X}_v$ | $P_{1-a}$ | $P_{1-v}$ | $P_{a-v}$ |
| EV | 2 | 16 | 100 | 1 | 8 | 115 | 0 | 0 | 110 | 1 | 2 | 1 | non | non | non |
| RD | 56 | 29 | 100 | 52 | 19 | 115 | 79 | 26 | 110 | 4 | -23 | -27 | non | **** | **** |
| VOT | 54 | 36 | 100 | 52 | 19 | 115 | 79 | 26 | 110 | 2 | -25 | -27 | non | **** | **** |

Table 19. Group *S1.*

| | /labials/ | | | /alveolars/ | | | /velars/ | | | differences of means | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_1$ | $s_1$ | $N_1$ | $\bar{X}_a$ | $s_a$ | $N_a$ | $\bar{X}_v$ | $s_v$ | $N_v$ | $\bar{X}_1-\bar{X}_a$ | $\bar{X}_1-\bar{X}_v$ | $\bar{X}_a-\bar{X}_v$ | $P_{1-a}$ | $P_{1-v}$ | $P_{a-v}$ |
| EV | 4 | 17 | 100 | 2 | 13 | 115 | 2 | 13 | 110 | 2 | 2 | 0 | non | non | non |
| RD | 24 | 22 | 100 | 31 | 18 | 115 | 48 | 21 | 110 | -7 | -24 | -17 | ** | **** | **** |
| VOT | 21 | 26 | 100 | 31 | 18 | 115 | 48 | 21 | 110 | -10 | -27 | -17 | **** | **** | **** |

Tables 20-22. The effect of the place features /labial/, /alveolar/ and /velar/ on the parameters EV, RD and VOT of the word initial /lenes/.

Table 20. Group *Engl.*

| | /labials/ | | | /alveolars/ | | | /velars/ | | | differences of means | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_1$ | $s_1$ | $N_1$ | $\bar{X}_a$ | $s_a$ | $N_a$ | $\bar{X}_v$ | $s_v$ | $N_v$ | $\bar{X}_1-\bar{X}_a$ | $\bar{X}_1-\bar{X}_v$ | $\bar{X}_a-\bar{X}_v$ | $P_{1-a}$ | $P_{1-v}$ | $P_{a-v}$ |
| EV | 65 | 61 | 95 | 53 | 56 | 95 | 56 | 61 | 70 | 12 | 9 | -3 | non | non | non |
| RD | 7 | 9 | 95 | 11 | 7 | 95 | 18 | 8 | 70 | -4 | -11 | -7 | **** | **** | **** |
| VOT | -61 | 66 | 95 | -46 | 63 | 95 | -47 | 70 | 70 | -15 | -14 | 1 | non | non | non |

Table 21. Group *S2.*

| | /labials/ | | | /alveolars/ | | | /velars/ | | | differences of means | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_1$ | $s_1$ | $N_1$ | $\bar{X}_a$ | $s_a$ | $N_a$ | $\bar{X}_v$ | $s_v$ | $N_v$ | $\bar{X}_1-\bar{X}_a$ | $\bar{X}_1-\bar{X}_v$ | $\bar{X}_a-\bar{X}_v$ | $P_{1-a}$ | $P_{1-v}$ | $P_{a-v}$ |
| EV | 92 | 32 | 95 | 67 | 40 | 95 | 77 | 36 | 70 | 25 | 15 | -10 | **** | *** | non |
| RD | 1 | 3 | 95 | 12 | 17 | 95 | 14 | 11 | 70 | -11 | -13 | -2 | **** | **** | non |
| VOT | -92 | 33 | 95 | -60 | 52 | 95 | -76 | 39 | 70 | -32 | -16 | 16 | **** | **** | * |

Table 22. Group *S1.*

| | /labials/ | | | /alveolars/ | | | /velars/ | | | differences of means | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_1$ | $s_1$ | $N_1$ | $\bar{X}_a$ | $s_a$ | $N_a$ | $\bar{X}_v$ | $s_v$ | $N_v$ | $\bar{X}_1-\bar{X}_a$ | $\bar{X}_1-\bar{X}_v$ | $\bar{X}_a-\bar{X}_v$ | $P_{1-a}$ | $P_{1-v}$ | $P_{a-v}$ |
| EV | 37 | 49 | 95 | 32 | 40 | 95 | 31 | 43 | 70 | 5 | 6 | 1 | non | non | non |
| RD | 7 | 12 | 95 | 10 | 10 | 95 | 30 | 23 | 70 | -3 | -23 | -20 | * | **** | **** |
| VOT | -30 | 55 | 95 | -21 | 46 | 95 | -4 | 61 | 70 | -9 | -26 | -17 | non | **** | * |

release duration or RD used in this study is essentially dependent on the extent of aspiration (although it also includes any frictional noise produced at the constriction just after the explosion) it can be said that the longer the distance between the glottis and the oral closure the sooner the glottis starts vibrating after the release of the oral closure. This kind of formulation of the regularities would rather suggest an aerodynamic explanation for the differences, although factors such as differences in initial stop closure durations might just as well be the reason. However, no evidence seems to be available at present for any kind of explanation.

*The differences between the groups.* — By and large, it seems that the word initial stops of the three groups differ more in degree than in kind. As for the /fortis/-/lenis/ opposition, no group used a cue that the other groups completely failed to use (except the seemingly contradictory case of the duration of the following vowel or VD; however, this is a technical difference resulting from the kind of segmentation employed here). It was seen that the separation of the distinctive categories /fortis/ and /lenis/ was generally poorest by group *S1*. with group *S2*. occasionally having extreme separation exceeding that of the "model" group *Engl*. With regard to place of articulation all groups d[illegible]ayed similar tendencies.

THE WORD MEDIAL POSITION

*The /fortis/-/lenis/ distinction.* — Tables 23-25 present a general picture of the /fortis/-/lenis/ differences in the word medial position, pooled across the three places of production. Table 26 shows again in a more compact form the differences of means and their significance for the three groups of informants. The parameters tabulated are the duration of the preceding (stressed) vowel or VD, the silent interval or SI of the stop itself, the extent of voicing of (the silent interval of) the stop or EV, the release duration or RD and the total duration TD of the stop (comprising SI+RD).

Tables 23-26. The effect of the word medial /fortis/-/lenis/ distinction on the parameters VD (duration of the preceding vowel), SI (silent interval), EV (extent of voicing), RD (release duration) and TD (total duration (SI+RD) of the stop).

Table 23. Group *Engl.*

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_1$ | $s_1$ | $N_1$ | $\bar{X}_f$-$\bar{X}_1$ | P |
| VD | 100 | 29 | 95 | 104 | 26 | 100 | -4 | non |
| SI | 60 | 18 | 95 | 58 | 15 | 100 | 2 | non |
| EV | 0 | 0 | 95 | 50 | 18 | 100 | -50 | **** |
| RD | 49 | 17 | 95 | 14 | 12 | 100 | 35 | **** |
| TD | 109 | 14 | 95 | 72 | 15 | 100 | 37 | **** |

Table 24. Group *S2.*

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_1$ | $s_1$ | $N_1$ | $\bar{X}_f$-$\bar{X}_1$ | P |
| VD | 99 | 27 | 95 | 112 | 32 | 100 | -13 | **** |
| SI | 91 | 19 | 95 | 74 | 20 | 100 | 17 | **** |
| EV | 3 | 8 | 95 | 68 | 27 | 100 | -65 | **** |
| RD | 47 | 20 | 95 | 9 | 12 | 100 | 38 | **** |
| TD | 138 | 28 | 95 | 83 | 23 | 100 | 55 | **** |

Table 25. Group *S1.*

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_1$ | $s_1$ | $N_1$ | $\bar{X}_f$-$\bar{X}_1$ | P |
| VD | 90 | 25 | 95 | 103 | 35 | 100 | -13 | **** |
| SI | 93 | 21 | 95 | 75 | 24 | 100 | 18 | **** |
| EV | 6 | 15 | 95 | 44 | 33 | 100 | -38 | **** |
| RD | 30 | 17 | 95 | 13 | 14 | 100 | 17 | **** |
| TD | 123 | 25 | 95 | 88 | 31 | 100 | 35 | **** |

Table 26. Comparison of the groups.

| | $\bar{X}_f$-$\bar{X}_1$ | | | P | | |
|---|---|---|---|---|---|---|
| | *Engl.* | *S2.* | *S1.* | *Engl.* | *S2.* | *S1.* |
| VD | -4 | -13 | -13 | non | **** | **** |
| SI | 2 | 17 | 18 | non | **** | **** |
| EV | -50 | -65 | -38 | **** | **** | **** |
| RD | 35 | 38 | 17 | **** | **** | **** |
| TD | 37 | 55 | 35 | **** | **** | **** |

In all groups a compensatory relationship between the duration of the preceding vowel and the silent interval of the stop can be observed. Thus a longer silent interval of the /fortes/ is almost invariably associated with a shorter duration of the preceding vowel. For group *Engl.*, however, the /fortis/-/lenis/ differences with regard to the two parameters are negligible and moreover statistically nonsignificant. It will be seen below that this is caused by the fact that in this group the alveolars present an opposite tendency with regard to the duration of the silent interval, /d/ having on an average a longer one than /t/. However, before going into the separate data for each place of articulation some further observations concerning the data in Tables 23-26 will be made.

It is remarkable that the absolute durations of the silent intervals of both the /fortes/ and the /lenes/ are much greater in the two Finnish groups than in the English group (in /fortes/ 93, 91, and 60 msec. and in /lenes/ 75, 74 and 50 msec. for the groups *S1.*, *S2.* and *Engl.*, respectively). It is not simply a matter of different speaking rate as the vowel durations show rather an opposite tendency (see also Tables 45-47 below where it is obvious that the absolute vowel durations used by group *Engl.* are longer than those used by the Finnish groups). It seems rather that it is a question of a different vowel/consonant ratio, and it would be interesting to know how much it contributes to the foreign accent noticed in the speech of Finns by native speakers of English. Part of the observed differences (at least for group *S1.*) could conceivably be explainable on the basis of the fact that the spelling of some of the medial stops (e.g. *patty*) consists of two identical graphemes just as the spelling of Finnish geminate consonants, and consequently some of these stops were produced phonetically long according to Finnish rules of pronunciation. That this is not the whole explanation is evident for the following reason: if the Finnish informants had indeed produced basically two kinds of stops, one corresponding to Finnish single stops and the other to geminates, the mean ($\bar{X}$) would naturally become a little higher than that of single stops alone. However, such a dichotomy of the durations of the silent intervals would automatically be reflected in a large standard deviation (s), whereas it can be seen that the standard deviations of groups *S1.* and *S2.* (/fortes/: 21 and 19 msec.; /lenes/: 24 and 20 msec., respectively) are not very much larger than those of group *Engl.* (18 and 15 msec.). According to Lehtonen (1970: 70-71) the average durations of Finnish single stops vary around 100 msec., while those of the geminates vary around 200 msec., from which figures it can be seen that the durations of the silent intervals produced by the Finnish groups do not differ markedly from the durations of average Finnish single stops (although in Lehtonen's measurements the small burst often accompanying the Finnish stops was also included).

As regards voicing in medial position it is again noteworthy that group *Engl.* is the only one without even occasional or partial voicing of the /fortes/. Otherwise a pattern similar to the voicing of initial stops can be observed, with group *S2.* having the maximum of voicing of the /lenes/ and group *Engl.* assuming an intermediate position. It can be seen in the Tables that the absolute means for all /lenes/ in this position are 50, 68 and 44 msec. for groups *Engl.*, *S2.* and *S1.*, respectively. Also relatively, i.e. as percentage of the duration of voicing of the silent interval, group *S2.* ranks highest on the list, the corresponding percentages being 86%, 92% and 59%. It is also noteworthy that group *S1.*, although exhibiting an approximately equal duration (in absolute terms) of voicing in the /lenes/ as group *Engl.*, yet has much larger standard deviation (s), namely 33 msec. against 18 msec. This indicates that voicing is more irregular in the Finnish group, either in the speech of single individuals or between members of the group.

The release durations are approximately the same for groups *Engl.* and *S2.*, with group *S1.* having the shortest RD. Generally it can be said that the differences between the means of the /fortis/ and /lenis/ values for the parameters that show statistically significant differences for the "model" group *Engl.* (thus disregarding VD and SI) are smallest for group *S1.*, while the standard deviations are the greatest for this group. These two facts are a clear indication of greater overlapping of the categories in this group.

Tables 27-35 show the /fortis/-/lenis/ distinction for the three places of articulation separately, Tables 27-29 showing the labials for each group, Tables 30-32 showing the alveolars and Tables 33-35 the velars. In Tables 36-38 the corresponding differences of means and their statistical significance have been reorganized to enable a comparison of the groups.

In Chart 2 (which is based on the VD and SI data of Tables 27-35) it can again be seen that in each group and through all places of articulation a longer silent interval SI is invariably associated with a shorter

Tables 27-29. The effect of the word medial /fortis/-/lenis/ distinction on the labial stops.

Table 27. Group *Engl.*

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_f$-$\bar{X}_l$ | P |
| VD | 87 | 25 | 25 | 106 | 22 | 35 | -19 | **** |
| SI | 80 | 15 | 25 | 72 | 12 | 35 | 8 | ** |
| EV | 0 | 0 | 25 | 65 | 25 | 35 | -65 | **** |
| RD | 30 | 13 | 25 | 7 | 7 | 35 | 23 | **** |
| TD | 110 | 15 | 25 | 79 | 12 | 35 | 31 | |

Table 28. Group *S2.*

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_f$-$\bar{X}_l$ | P |
| VD | 85 | 22 | 25 | 105 | 23 | 35 | -20 | **** |
| SI | 108 | 19 | 25 | 90 | 16 | 35 | 18 | **** |
| EV | 9 | 13 | 25 | 90 | 16 | 35 | -81 | **** |
| RD | 32 | 18 | 25 | 5 | 6 | 35 | 27 | **** |
| TD | 140 | 37 | 25 | 95 | 22 | 35 | 45 | **** |

Table 29. Group *S1.*

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_f$-$\bar{X}_l$ | P |
| VD | 84 | 23 | 25 | 95 | 21 | 35 | -11 | non |
| SI | 100 | 22 | 25 | 88 | 17 | 35 | 12 | ** |
| EV | 9 | 14 | 25 | 49 | 38 | 35 | -40 | **** |
| RD | 19 | 12 | 25 | 8 | 11 | 35 | 11 | **** |
| TD | 119 | 26 | 25 | 96 | 22 | 35 | 23 | **** |

duration of the preceding vowel, although the differences are generally small and not always statistically significant. Further it can be seen that it is the /fortes/ that exhibit the longer silent interval, with a single exception: the /d/'s of group *Engl.* have a longer silent interval than their /t/'s (48 msec. against 47 msec., see Table 30). The difference, however, is

Tables 30-32. The effect of the word medial /fortis/-/lenis/ distinction on the alveolar stops.

Table 30. Group *Engl.*

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_f$-$\bar{X}_l$ | P |
| VD | 110 | 28 | 40 | 97 | 20 | 35 | 13 | ** |
| SI | 47 | 13 | 40 | 48 | 10 | 35 | -1 | non |
| EV | 0 | 0 | 40 | 44 | 14 | 35 | -44 | **** |
| RD | 61 | 11 | 40 | 13 | 10 | 35 | 48 | **** |
| TD | 108 | 15 | 40 | 61 | 11 | 35 | 47 | **** |

Table 31. Group *S2*.

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_f$-$\bar{X}_l$ | P |
| VD | 106 | 26 | 40 | 116 | 40 | 35 | -10 | non |
| SI | 88 | 16 | 40 | 60 | 15 | 35 | 28 | **** |
| EV | 6 | 4 | 40 | 56 | 16 | 35 | -50 | **** |
| RD | 49 | 17 | 40 | 8 | 9 | 35 | 41 | **** |
| TD | 137 | 19 | 40 | 68 | 21 | 35 | 69 | **** |

Table 32. Group *S1*.

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_f$-$\bar{X}_l$ | P |
| VD | 94 | 25 | 40 | 113 | 50 | 35 | -19 | * |
| SI | 91 | 23 | 40 | 54 | 20 | 35 | 37 | **** |
| EV | 2 | 8 | 40 | 51 | 16 | 35 | -49 | **** |
| RD | 34 | 18 | 40 | 6 | 8 | 35 | 28 | **** |
| TD | 125 | 27 | 40 | 60 | 21 | 35 | 65 | **** |

negligible and moreover statistically nonsignificant; more interesting is the fact that even here a longer silent interval is associated with a shorter duration of the preceding vowel. Thus, unlike all the other /lenes/ of the same (or, for that matter, of the other) group(s), the /d/'s have caused a shortening of the preceding vowel, a shortening which moreover is

Tables 33-35. The effect of the word medial /fortis/-/lenis/ distinction on the velar stops.

Table 33. Group *Engl.*

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_f$-$\bar{X}_l$ | P |
| VD | 99 | 29 | 30 | 110 | 34 | 30 | -11 | non |
| SI | 59 | 10 | 30 | 52 | 10 | 30 | 7 | ** |
| EV | 0 | 0 | 30 | 47 | 14 | 30 | -47 | **** |
| RD | 48 | 11 | 30 | 23 | 13 | 30 | 25 | **** |
| TD | 107 | 12 | 30 | 75 | 14 | 30 | 32 | **** |

Table 34. Group *S2*.

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_f$-$\bar{X}_l$ | P |
| VD | 100 | 29 | 30 | 115 | 30 | 30 | -15 | non |
| SI | 82 | 13 | 30 | 71 | 17 | 30 | 11 | *** |
| EV | 0 | 0 | 30 | 56 | 30 | 30 | -56 | **** |
| RD | 56 | 17 | 30 | 15 | 17 | 30 | 41 | **** |
| TD | 132 | 31 | 30 | 85 | 21 | 30 | 47 | **** |

Table 35. Group *S1*.

| | /fortes/ | | | /lenes/ | | | difference of means | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_f$ | $s_f$ | $N_f$ | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_f$-$\bar{X}_l$ | P |
| VD | 90 | 25 | 30 | 100 | 24 | 30 | -10 | non |
| SI | 91 | 16 | 30 | 83 | 18 | 30 | 8 | non |
| EV | 8 | 22 | 30 | 30 | 37 | 30 | -22 | *** |
| RD | 35 | 16 | 30 | 25 | 15 | 30 | 10 | * |
| TD | 126 | 23 | 30 | 108 | 28 | 30 | 18 | *** |

statistically significant. This seems to indicate rather clearly that the duration of the preceding vowel is not phonologically conditioned in the way that a longer or a shorter duration would invariably be connected with one or the other of the two linguistic categories /fortis/ and /lenis/. Rather, the durational relations seem to speak for a tendency to keep the



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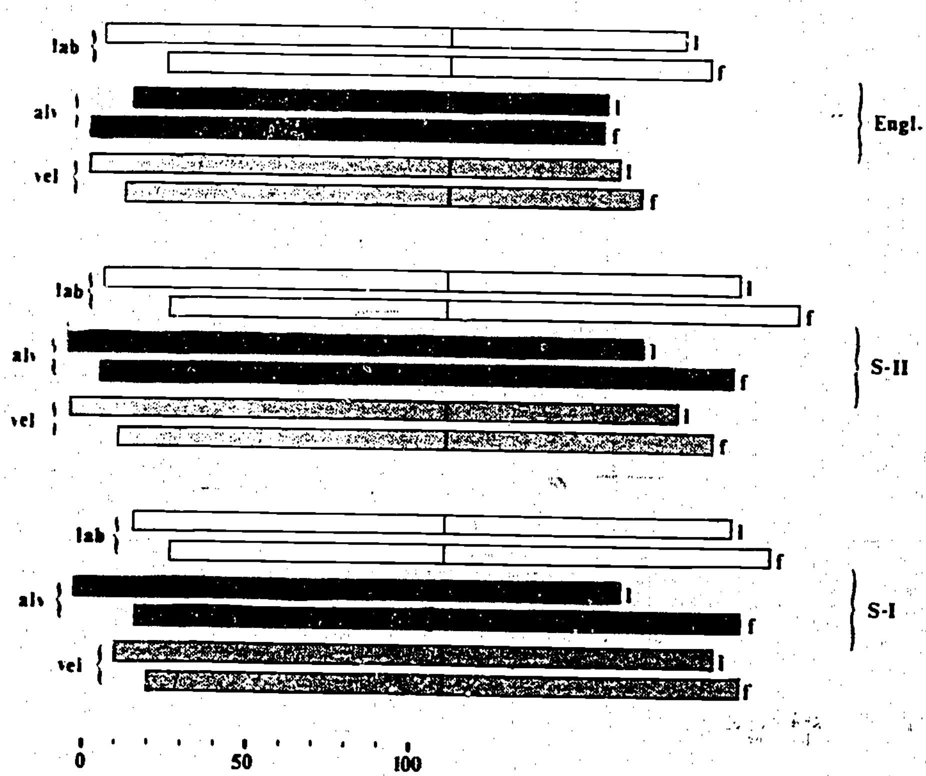
CHART 2. The durations of the preceding vowel (VD) and the silent interval (SI) of the word medial stops. The units on the time scale are milliseconds; $f$ and $\ell$ stand for the categories /fortis/ and /lenis/, respectively.



Tables 36–38. Summary of the effect of the word medial /fortis/-/lenis/ distinction on stops of different place of articulation.

Table 36. The labial stops.

| | $\bar{X}_f-\bar{X}_l$ | | | p | | |
|---|---|---|---|---|---|---|
| | *Engl.* | *S2.* | *S1.* | *Engl.* | *S2.* | *S1.* |
| VD | -19 | -20 | -11 | **** | **** | non |
| SI | 8 | 18 | 12 | ** | **** | **** |
| EV | -65 | -81 | -40 | **** | **** | **** |
| RD | 23 | 27 | 11 | **** | **** | **** |
| TD | 31 | 45 | 23 | **** | **** | **** |

Table 37. The alveolar stops.

| | $\bar{X}_f-\bar{X}_l$ | | | p | | |
|---|---|---|---|---|---|---|
| | *Engl.* | *S2.* | *S1.* | *Engl.* | *S2.* | *S1.* |
| VD | 13 | -10 | -19 | ** | non | * |
| SI | -1 | 28 | 37 | non | **** | **** |
| EV | -44 | -50 | -49 | **** | **** | **** |
| RD | 48 | 41 | 28 | **** | **** | **** |
| TD | 47 | 69 | 65 | **** | **** | **** |

Table 38. The velar stops.

| | $\bar{X}_f-\bar{X}_l$ | | | p | | |
|---|---|---|---|---|---|---|
| | *Engl.* | *S2.* | *S1.* | *Engl.* | *S2.* | *S1.* |
| VD | -11 | -15 | -10 | non | non | non |
| SI | 7 | 11 | 8 | ** | *** | non |
| EV | -47 | -56 | -22 | **** | **** | *** |
| RD | 25 | 41 | 10 | **** | **** | * |
| TD | 32 | 47 | 18 | **** | **** | *** |

total duration of the *CV* sequence constant. On the whole, it can be said that the duration of the silent interval does not provide a reliable separation of the two categories of stops for group *Engl.*, for even in the labials and velars the differences, although statistically significant, are likely to be too small to have any real cue value in speech perception. Only group *S2.* displays a systematic and statistically strongly significant difference with regard to this parameter through all places of production.

In general the observations made above in connection with Tables 23-26 seem to be valid for each place of articulation, with some notable exceptions. Thus it can be seen that group *S1.* has a remarkable long extent of relative (i.e. EV/SI) voicing in /d/ as compared to the other /lenes/. This is no doubt due to the fact that this is a position where the Finnish /d/ occurs and consequently the sound has not presented any real difficulties for the Finnish speakers. That the same trend is not so conspicuous in the data of group *S2.* is most likely due to the fact that they again have extensive voicing in *all* /lenes/. It is also interesting to note that although the differences in the durations of the silent intervals of the /fortes/ and the /lenes/ are usually very small, as already seen above, the alveolars of both Finnish groups form an exception, with /d/ having a clearly shorter average duration of the silent interval than /t/ (the differences being 37 and 28 msec. for groups *S1.* and *S1.*, respectively, see Tables 31 and 32). This is in accordance with reports to the effect that the Finnish /d/ is noticeably shorter than /t/ (see for example Lehtonen 1970: 71). It is also clear that this cue is not used in English, at least not by the informants used in the present study.

*The effect of the place of production.* — In Tables 39-44 the data on the medial stops have been reorganized for comparison of the differences between the places of production and their statistical significance. The durations of the silent intervals (SI) and release durations (RD) are presented graphically in Chart 3. A few generalizations concerning the data will be pointed out here, although the origins of these differences interest us only to the extent that they are connected with the /fortis/-/lenis/ distinction. Thus it can be seen that in all medial stops, both in the /fortes/ and in the /lenes/, the labials have the longest duration of the silent interval. This difference is statistically strongly significant in all groups and both categories with the exception of the /fortes/ of group *S1.* which nevertheless have a nonsignificant trend in the same direction (see Table 41). Similarly it can be said that there are no statistically significant exceptions to the general

Tables 39-41. The effect of the place features /labial/, /alveolar/ and /velar/ on the parameters VD, SI, EV, RD and TD of the word medial /fortes/.

Table 39. Group *Engl.*

| | /labials/ | | | /alveolars/ | | | /velars/ | | | differences of means | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_a$ | $s_a$ | $N_a$ | $\bar{X}_v$ | $s_v$ | $N_v$ | $\bar{X}_l-\bar{X}_a$ | $\bar{X}_l-\bar{X}_v$ | $\bar{X}_a-\bar{X}_v$ | $P_{l-a}$ | $P_{l-v}$ | $P_{a-v}$ |
| VD | 87 | 25 | 25 | 110 | 28 | 40 | 99 | 29 | 30 | -23 | -12 | 11 | **** | non | non |
| SI | 80 | 15 | 25 | 47 | 13 | 40 | 59 | 10 | 30 | 33 | 21 | -12 | **** | **** | **** |
| EV | 0 | 0 | 25 | 0 | 0 | 40 | 0 | 0 | 30 | 0 | 0 | 0 | non | non | non |
| RD | 30 | 13 | 25 | 61 | 11 | 40 | 48 | 11 | 30 | -31 | -18 | 13 | **** | **** | **** |
| TD | 110 | 15 | 25 | 108 | 15 | 40 | 107 | 12 | 30 | 2 | 3 | 1 | non | non | non |

Table 40. Group *S2.*

| | /labials/ | | | /alveolars/ | | | /velars/ | | | differences of means | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_a$ | $s_a$ | $N_a$ | $\bar{X}_v$ | $s_v$ | $N_v$ | $\bar{X}_l-\bar{X}_a$ | $\bar{X}_l-\bar{X}_v$ | $\bar{X}_a-\bar{X}_v$ | $P_{l-a}$ | $P_{l-v}$ | $P_{a-v}$ |
| VD | 85 | 22 | 25 | 106 | 26 | 40 | 100 | 29 | 30 | -21 | -15 | 6 | **** | * | non |
| SI | 108 | 19 | 25 | 88 | 16 | 40 | 82 | 13 | 30 | 20 | 26 | 6 | **** | **** | non |
| EV | 9 | 13 | 25 | 1 | 4 | 40 | 0 | 0 | 30 | 8 | 9 | 1 | **** | **** | non |
| RD | 32 | 18 | 25 | 49 | 17 | 40 | 56 | 17 | 30 | -17 | -24 | -7 | **** | **** | non |
| TD | 135 | 37 | 25 | 137 | 19 | 40 | 132 | 31 | 30 | -2 | 3 | 5 | non | non | non |

Table 41. Group *S1.*

| | /labials/ | | | /alveolars/ | | | /velars/ | | | differences of means | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_a$ | $s_a$ | $N_a$ | $\bar{X}_v$ | $s_v$ | $N_v$ | $\bar{X}_l-\bar{X}_a$ | $\bar{X}_l-\bar{X}_v$ | $\bar{X}_a-\bar{X}_v$ | $P_{l-a}$ | $P_{l-v}$ | $P_{a-v}$ |
| VD | 84 | 23 | 25 | 94 | 25 | 40 | 90 | 25 | 30 | -10 | -6 | 4 | non | non | non |
| SI | 100 | 22 | 25 | 91 | 23 | 40 | 91 | 16 | 30 | 9 | 9 | 0 | non | non | non |
| EV | 9 | 14 | 25 | 2 | 8 | 40 | 8 | 22 | 30 | 7 | 1 | -6 | ** | non | non |
| RD | 19 | 12 | 25 | 34 | 18 | 40 | 35 | 16 | 30 | -15 | -16 | -1 | **** | **** | non |
| TD | 119 | 26 | 25 | 125 | 27 | 40 | 126 | 23 | 30 | -6 | -7 | -1 | non | non | non |

Tables 42-44. The effect of the place features /labial/, /alveolar/ and /velar/ on the parameters VD, SI, EV, RD and TD of the word medial /lenes/.

Table 42. Group *Engl.*

| | /labials/ | | | /alveolars/ | | | /velars/ | | | differences of means | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_a$ | $s_a$ | $N_a$ | $\bar{X}_v$ | $s_v$ | $N_v$ | $\bar{X}_l-\bar{X}_a$ | $\bar{X}_l-\bar{X}_v$ | $\bar{X}_a-\bar{X}_v$ | $P_{l-a}$ | $P_{l-v}$ | $P_{a-v}$ |
| VD | 106 | 22 | 35 | 97 | 20 | 35 | 110 | 34 | 30 | 9 | -4 | -13 | non | non | * |
| SI | 72 | 12 | 35 | 48 | 10 | 35 | 52 | 10 | 30 | 24 | 20 | -4 | **** | **** | non |
| EV | 65 | 20 | 35 | 44 | 14 | 35 | 47 | 14 | 30 | 21 | 18 | -3 | **** | *** | non |
| RD | 7 | 7 | 35 | 13 | 10 | 35 | 23 | 13 | 30 | -6 | -16 | -10 | *** | **** | **** |
| TD | 79 | 12 | 35 | 61 | 11 | 35 | 75 | 14 | 30 | 18 | 4 | -14 | **** | non | **** |

Table 43. Group *S2.*

| | /labials/ | | | /alveolars/ | | | /velars/ | | | differences of means | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_a$ | $s_a$ | $N_a$ | $\bar{X}_v$ | $s_v$ | $N_v$ | $\bar{X}_l-\bar{X}_a$ | $\bar{X}_l-\bar{X}_v$ | $\bar{X}_a-\bar{X}_v$ | $P_{l-a}$ | $P_{l-v}$ | $P_{a-v}$ |
| VD | 105 | 23 | 35 | 116 | 40 | 35 | 115 | 30 | 30 | -11 | -10 | 1 | non | non | non |
| SI | 90 | 16 | 35 | 60 | 15 | 35 | 71 | 17 | 30 | 30 | 19 | -11 | **** | **** | ** |
| EV | 90 | 16 | 35 | 56 | 16 | 35 | 56 | 30 | 30 | 34 | 34 | 0 | **** | **** | non |
| RD | 5 | 6 | 35 | 8 | 9 | 35 | 15 | 17 | 30 | -3 | -10 | -7 | non | **** | * |
| TD | 95 | 22 | 35 | 69 | 21 | 35 | 85 | 21 | 30 | 26 | 10 | -16 | **** | non | *** |

Table 44. Group *S1.*

| | /labials/ | | | /alveolars/ | | | /velars/ | | | differences of means | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_a$ | $s_a$ | $N_a$ | $\bar{X}_v$ | $s_v$ | $N_v$ | $\bar{X}_l-\bar{X}_a$ | $\bar{X}_l-\bar{X}_v$ | $\bar{X}_a-\bar{X}_v$ | $P_{l-a}$ | $P_{l-v}$ | $P_{a-v}$ |
| VD | 95 | 21 | 35 | 113 | 50 | 35 | 100 | 24 | 30 | -18 | -5 | 13 | non | non | non |
| SI | 88 | 17 | 35 | 54 | 20 | 35 | 83 | 18 | 30 | 34 | 5 | -29 | **** | non | **** |
| EV | 49 | 38 | 35 | 51 | 16 | 35 | 30 | 37 | 30 | -2 | 19 | 21 | non | * | *** |
| RD | 8 | 11 | 35 | 6 | 8 | 35 | 25 | 15 | 30 | 2 | -17 | -19 | non | **** | **** |
| TD | 96 | 22 | 35 | 60 | 21 | 35 | 106 | 28 | 30 | 33 | -10 | -46 | **** | non | **** |





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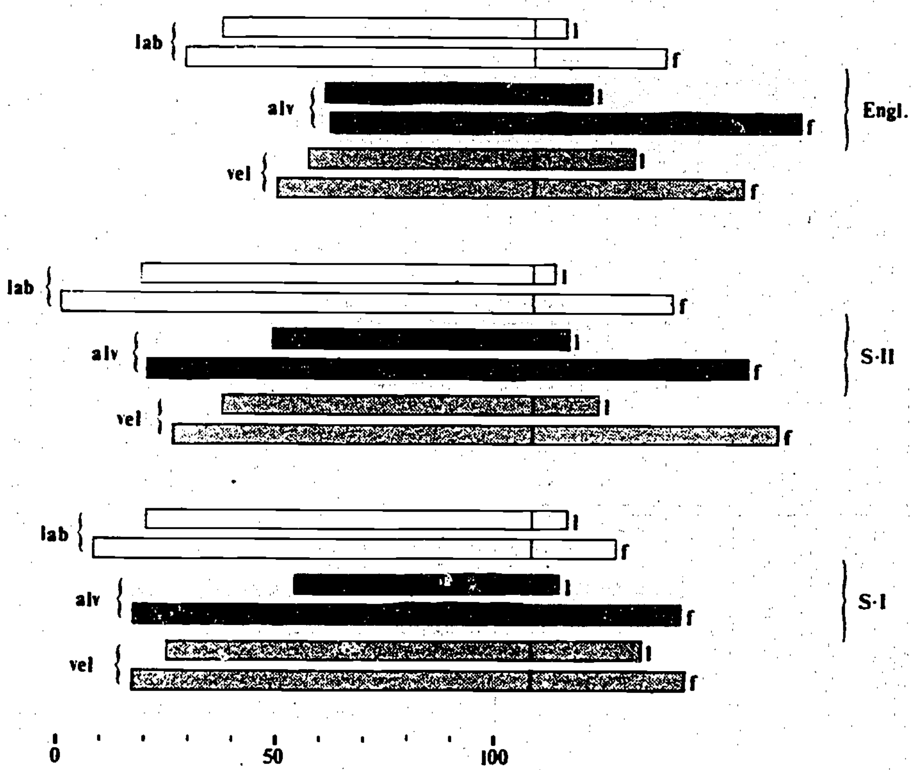
CHART 3. The durations of the silent interval (SI) and release duration (RD) of the word medial stops. The units on the time scale are milliseconds; ƒ and ℓ stand for the categories /fortis/ and /lenis/, respectively.



rule that the velar stops have a longer silent interval than the alveolar ones, although this tendency is much weaker. These findings are in accordance with those of Fischer-Jørgensen (1964) who has studied the effect of place of articulation on sound duration in greater detail. Also Lehtonen (1970: 70-75) has found the order /p/>/k/>/t/ in the production of medial plosives.

Table 42 and Chart 3 show that there are statistically strongly significant differences between the release durations RD of /b/, /d/ and /g/ of group *Engl.* As in the case of the word initial plosives (see Table 20), the velar stop /g/ has the longest and the labial stop /b/ the shortest release duration. Neither are there any significant exceptions to this tendency in the medial /lenes/ of the two Finnish groups (Tables 43 and 44 and Chart 3). On the other hand, the /fortes/ of the same position exhibit a different picture. Thus it can be seen in Table 39 and in the graphic representation in Chart 4 that statistically strongly significant differences exist also here between the release durations of the three places of articulation in the productions of group *Engl.*, although the order of magnitude is different from the /lenes/. Now the alveolar stop /t/ has the longest and the velar stop /k/ the intermediate release duration. For the corresponding means of the two Finnish groups (Tables 40 and 41) the only statistically significant difference is that between /p/ and the other /fortes/, the former having a systematically shorter release duration than the latter two which do not differ from each other statistically in this respect. It may seem odd that the order of magnitude of the three places of production is different in the two categories, one would rather have expected phonological symmetry to be reflected in the durational relations. At this stage a few more observations deserve to be pointed out although no explanations will as yet be attempted. Thus it can be seen that, with regard to the word medial /lenes/, statistically significant differences exist for all groups between the total durations TD (i.e., SI+RD) of the stops (Tables 42-44), whereas no statistically significant ones exist in this respect between /p/, /t/ and /k/ (Tables 39-41). On the other hand, statistically significant differences exist between the places of articulation with regard to the silent interval SI, except for the /fortes/ of group *S1*. With a comparison of the SI and RD data of the /fortes/ it is possible to assess that a practically perfect



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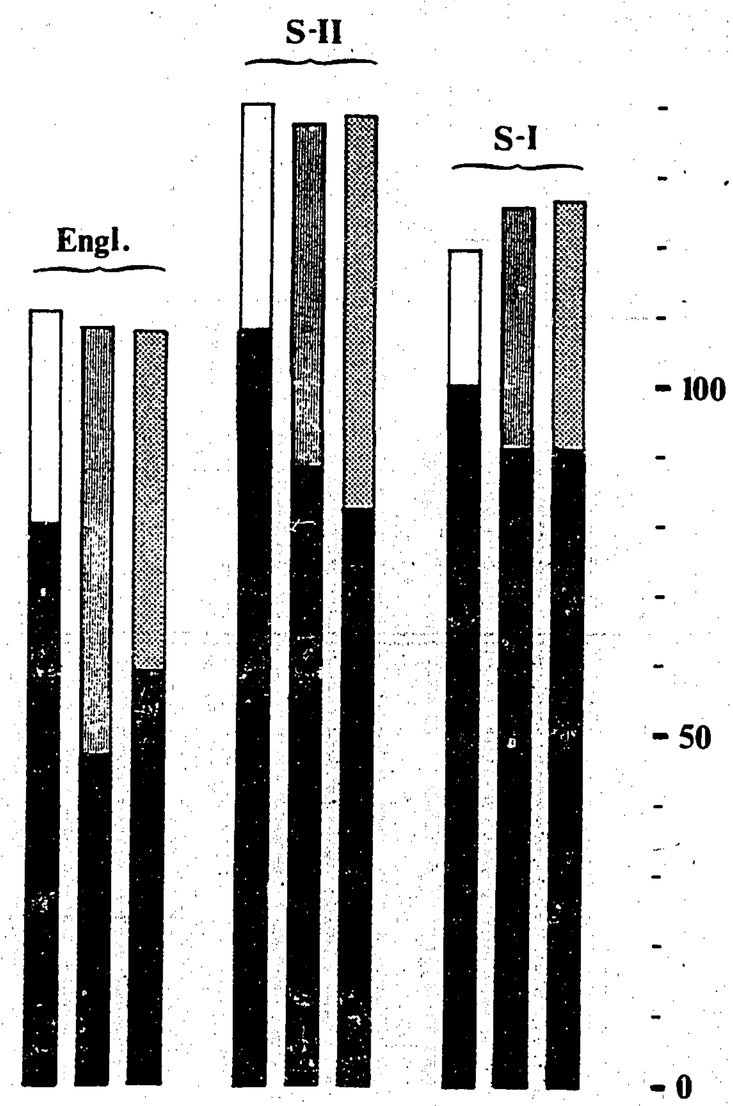
CHART 4. The durations of the silent interval (black column) and release duration of the word medial /fortes/. The units on the time scale are milliseconds. The white columns imply labial, the striped ones alveolar and the dotted ones velar stops.



reciprocal pattern obtains between the two measures. Thus differences in the duration of the SI are completely compensated for by differences in RD. It is clearly a matter of temporal coordination between laryngeal and supraglottal activities, and this is why differences between places of articulation may turn out to be helpful in the clarification of the mechanisms underlying the /ptk/-/bdg/ distinction in English. This point will be further elaborated in connection with the discussion of the physiological mechanisms below.

## THE WORD FINAL POSITION

*The effect of the vowel categories /tense/, /ae/ and /lax/ on the duration of the preceding vowel.* – Tables 45-47 present the results for the word final /fortis/-/lenis/ distinction for the three groups, with Table 48 showing only the differences of means and their statistical significance for an easier comparison of the groups. The parameters under investigation are the duration of the preceding vowel (belonging to one of the categories /tense/, /lax/ and /ae/) or VD, the duration of the silent interval of the stop or SI, and the extent of voicing of the stop or EV. In Chart 5 a summary of the effects of the vowel categories /tense/, /ae/ and /lax/ and the consonant categories /fortis/ and /lenis/ on the parameter VD is presented graphically.

Inspection of the Tables reveals that the inclusion of different vowel categories was useful in that interesting differences emerge between the groups with respect to the parameter VD. Looking first at the data on the duration of the vowels before the /fortis/ stops we can see that for group *Engl.* (Table 45) the /tense/ vowels have the longest and the /lax/ vowels the shortest VD, while the /ae/ vowels exhibit a duration approximately halfway between the two. The /tense/ vowels are 68 msec. or 58 per cent longer than the /lax/ ones, which is in good agreement with earlier published data. Wiik, for example, reports (1965: 115) a 65 per cent longer duration of the /long/ (=/tense/) vowels compared to that of the /short/ ones.

For groups *S2.* and *S1.* the same trends can be observed (Tables 46 and 47) although the ratios of the means form a markedly different pattern.

Tables 45-48. The effect of the word final /fortis/-/lenis/ distinction on the parameters VD (duration of the preceding vowel, three groups), SI (silent interval) and EV (extent of voicing of the stop).

Table 45. Group *Engl.*

| | /fortes/ $\bar{X}_f$ | $s_f$ | $N_f$ | /lenes/ $\bar{X}_l$ | $s_l$ | $N_l$ | difference of means $\bar{X}_f$-$\bar{X}_l$ | P |
|---|---|---|---|---|---|---|---|---|
| VD /tense/ | 186 | 61 | 80 | 335 | 42 | 30 | -149 | **** |
| VD /ae/ | 156 | 27 | 55 | 255 | 52 | 60 | -99 | **** |
| VD /lax/ | 118 | 28 | 75 | 192 | 35 | 90 | -74 | **** |
| SI | 102 | 24 | 210 | 75 | 19 | 180 | 27 | **** |
| EV | 0 | 0 | 210 | 56 | 28 | 180 | -56 | **** |

Table 46. Group *S2.*

| | /fortes/ $\bar{X}_f$ | $s_f$ | $N_f$ | /lenes/ $\bar{X}_l$ | $s_l$ | $N_l$ | difference of means $\bar{X}_f$-$\bar{X}_l$ | P |
|---|---|---|---|---|---|---|---|---|
| VD /tense/ | 252 | 41 | 79 | 277 | 32 | 31 | -25 | **** |
| VD /ae/ | 165 | 37 | 55 | 198 | 33 | 60 | -33 | **** |
| VD /lax/ | 132 | 27 | 75 | 168 | 34 | 90 | -36 | **** |
| SI | 115 | 26 | 210 | 89 | 23 | 180 | 26 | **** |
| EV | 3 | 10 | 210 | 62 | 38 | 180 | -59 | **** |

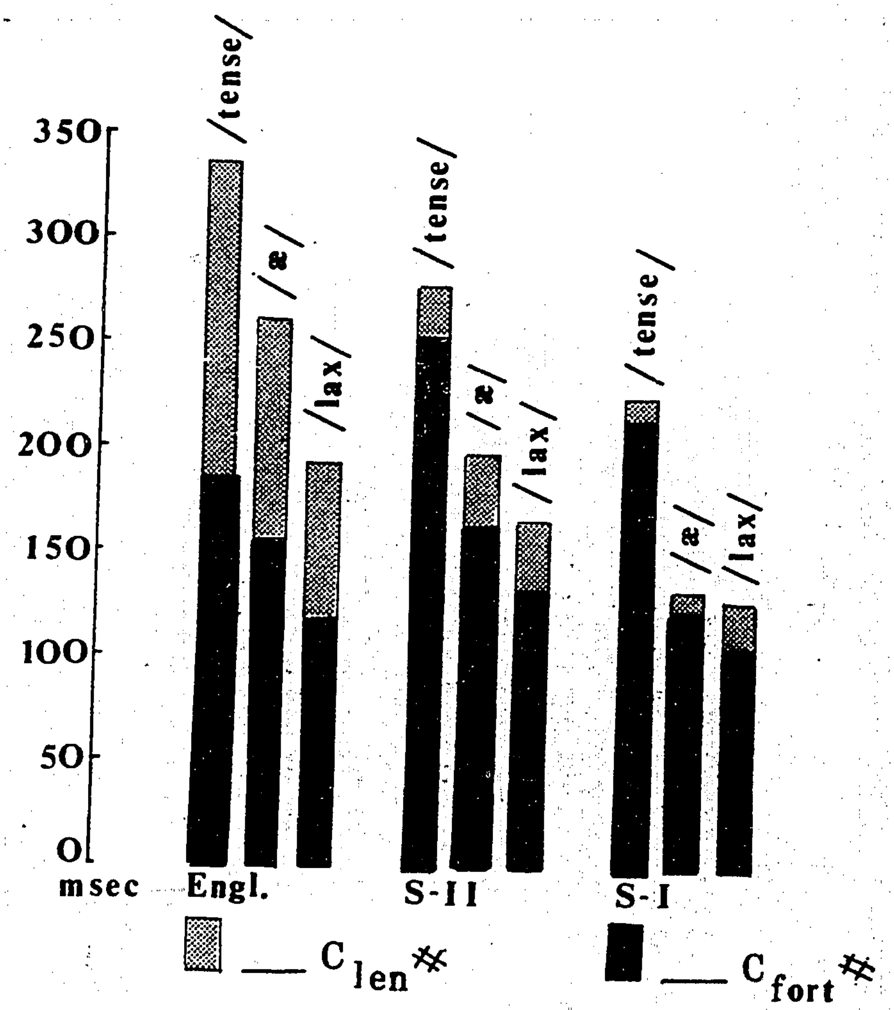
Table 47. Group *S1.*

| | /fortes/ $\bar{X}_f$ | $s_f$ | $N_f$ | /lenes/ $\bar{X}_l$ | $s_l$ | $N_l$ | difference of means $\bar{X}_f$-$\bar{X}_l$ | P |
|---|---|---|---|---|---|---|---|---|
| VD /tense/ | 215 | 55 | 80 | 228 | 49 | 30 | -13 | non |
| VD /ae/ | 124 | 26 | 55 | 133 | 34 | 60 | -9 | non |
| VD /lax/ | 106 | 25 | 75 | 123 | 30 | 90 | -17 | **** |
| SI | 105 | 37 | 210 | 96 | 32 | 180 | 9 | *** |
| EV | 2 | 7 | 210 | 16 | 23 | 180 | -14 | **** |

Table 48. Comparison of the groups.

| | $\bar{X}_f$-$\bar{X}_l$ *Engl.* | *S2.* | *S1.* | P *Engl.* | *S2.* | *S1.* |
|---|---|---|---|---|---|---|
| VD /tense/ | -149 | -25 | -13 | **** | **** | non |
| VD /ae/ | -99 | -33 | -9 | **** | **** | non |
| VD /lax/ | -74 | -36 | -17 | **** | **** | **** |
| SI | 27 | 26 | 9 | **** | **** | *** |
| EV | -56 | -59 | -14 | **** | **** | **** |

CHART 5. The effect of the /fortis/-/lenis/ character of the word final stops on the durations of the preceding /tense/, /ae/ and /lax/ vowels. The units on the time scale are milliseconds; ƒ and ℓ stand for the categories /fortis/ and /lenis/, respectively.



Thus for group *S2*. the /tense/ vowels preceding the /fortes/ are 120 msec. or 91 per cent longer than the /lax/ ones, for group *S1*. the corresponding figures are 109 msec. or 103 per cent. It is clear from these results that the Finnish groups have realized the /tense/-/lax/ distinction in a way different from that used by the English informants. Even in the absence of any spectral information it seems evident that the Finnish speakers have identified the distinction with the phonetically partly similar distinction of /single/ and /double/ vowels in Finnish which, however, rests almost totally on differences in duration. Thus the ratios of the /tense/ and /lax/ vowels for the two Finnish groups agree quite well with the reported ratios of Finnish /double/ and /single/ vowels (see for example Lehtonen 1970: 64 and Wiik 1965: 115). It would also seem that the /ae/ vowels of the Finnish groups would show less deviation from the /lax/ ones than is the case with the English group, although even here the differences seem to be too great to be explainable on the basis of the more open tongue position of the /ae/ vowels compared to most of the /lax/ vowels occurring in the test material (see Appendix A). The intermediate position taken by the /ae/ vowels for group *Engl*. (Table 45) reflects rather well the ambivalent or /neutral/ (see Wiik 1965: 49) character of the vowel with respect to the feature /tense/-/lax/ or /long/-/short/.

The data on the same vowel categories before the /lenis/ stops show a qualitatively similar but quantitatively somewhat different pattern (see the right hand sides of Tables 45-47). For group *Engl*. the /tense/ vowels are 143 msec. or 75 per cent longer than the /lax/ vowels in the same position, the mean of the /ae/ vowels again being approximately halfway between the two extremes. If we compare the corresponding figures obtained above for the vowels before the /fortes/ (68 msec. or 58 per cent) we can conclude that for the native speakers the "switch" from /lax/ to /tense/ follows more closely a pattern of a percentual increment than an absolute one, i.e. *ceteris paribus* the /tense/ vowels seem to be about 60-70 per cent longer in duration than the /lax/ ones. This seems to be roughly the principle; a closer examination would doubtless reveal some kind of interaction between various rules of temporal organization.

The Finnish groups, on the other hand, seem to possess a rule using an absolute increment for converting /lax/ vowels to /tense/ ones (the notions of "switch" or "conversion" are not meant to be taken literally, they are used solely for purposes of exposition). Thus the absolute differences of means of the two vowel categories before the /lenes/ are 109 msec. and 105 msec. for groups *S2* and *S1*, respectively, figures which match almost perfectly with those obtained before the /fortes/ (120 msec. and 109 msec., respectively). The corresponding per cent figures are 65 and 85 per cent, which do not differ from the corresponding percentage of the *Engl.* group (75 per cent), but this is an accidental and trivial similarity which results from the interaction of various rules affecting the duration of the vocalic segments. On the basis of the data it would seem that the "Finnish way" of converting /lax/ vowels to /tense/ ones consists of lengthening the vowel with approximately the duration of a /single/ Finnish vowel. The two Finnish groups do not seem to differ from each other in this respect.

*The effect of the word final /fortis/-/lenis/ distinction on the duration of the preceding vowel.* — Table 48 and Chart 5 summarize the differences of means of the relevant parameters and their significance for each of the three groups. All groups exhibit a lengthening of vowels of each category before the /lenis/ stops compared to those preceding the /fortis/ stops but there is great variation in the extent and nature of this lengthening. For group *Engl.* the differences between the means of the pre-/fortis/ and pre-/lenis/ VD values (or, to put it in another way, the lengthening caused by the /lenis/ character of the following stop) are 149 msec., 99 msec. and 74 msec. for the /tense/, /ae/ and /lax/ vowels, respectively. Expressed as a per cent value of the pre-/fortis/ vowels the corresponding lengthening figures are 80, 63 and 63 per cent for the three vowel categories, respectively. All of these differences are statistically strongly significant. Also these results are in good agreement with earlier published data, for example Wiik (1965: 115) reports a 92 per cent and 72 per cent lengthening of /long/ and /short/ vowels, respectively. On the basis of the present data it would seem that here, too, a percentual increase rather than an absolute one is used in English. On the whole, the differences in vowel duration caused by the word final /fortis/-/lenis/ distinction are here as in so many earlier studies so extensive that their significance in cueing the distinction in perception cannot be doubted.

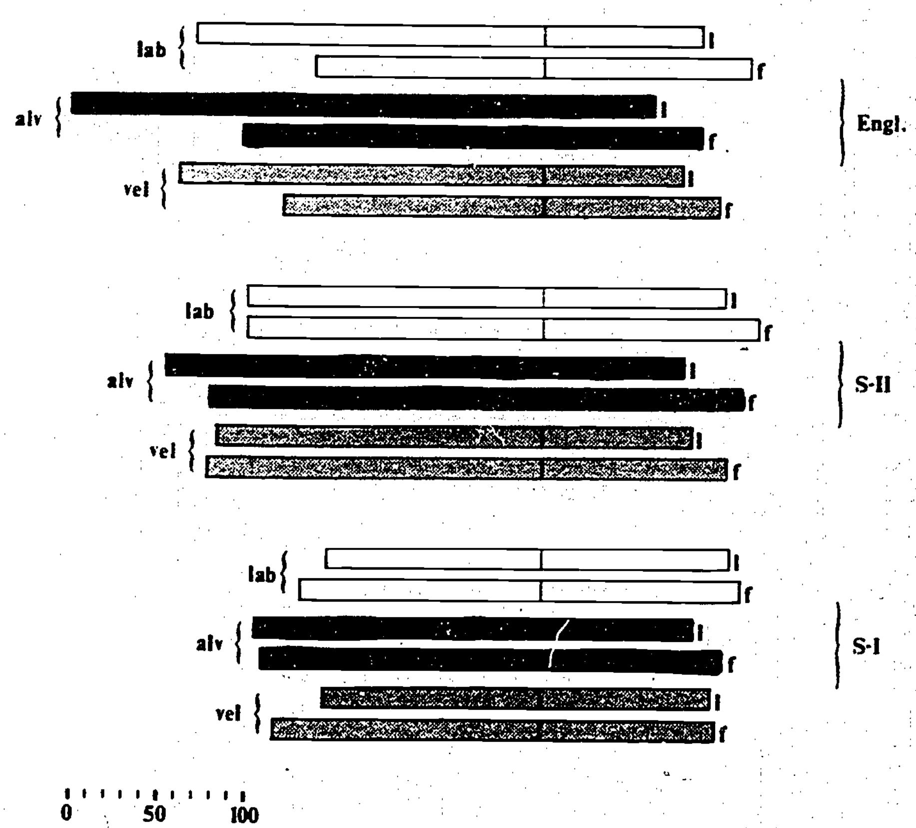
With regard to the VD preceding word final /fortis/-/lenis/ distinction group *S2* for once takes an intermediate position between the native English group and the less advanced Finnish group *S1*. For group *S2* the lengthening is also statistically strongly significant for each vowel category, but the absolute extents of the lengthening are much smaller than was the case with group *Engl.*, namely only around 30 msec. Thus it can be said that this group have for the most part failed to make use of a cue that is very powerful in English in signalling the word final /fortis/-/lenis/ distinction. Although the indications are rather weak one would also here (as in discussing the effect of the /tense/-/lax/ distinction of vowels above) be tempted to regard an absolute increment more likely than a relative one which seems to be favoured by the native speakers.

For group *SI* the /fortis/-/lenis/ differences in the means of the VD are almost negligible and moreover statistically nonsignificant in two out of three instances. It is likely that the weak tendency observable here reflects some kind of a universal, possibly articulatory constraint reported for so many languages (see for example Chen 1970). In general the results on this particular parameter are interpreted to once again confirm the notion that most of the lenthening of vowels (and of resonants in general) occurring in English before word final /lenis/ obstruents is due to a language specific, idiomatic and acquired habit which each child in an English-speaking community learns as a part of the sound system of his/her native language.

In Charts 7-9 the effects of the two factors influencing the parameter VD have been summarized for the three groups (for comparison see Wiik 1965: 115). The letters I: and I stand for the classes of /tense/ and /lax/ vowels and the letters T and D for the /fortis/ and /lenis/ stops, respectively. The arrows indicate the direction of the "lengthening", the figures give the absolute difference in msec. values and (in parentheses) the percentual lengthening.

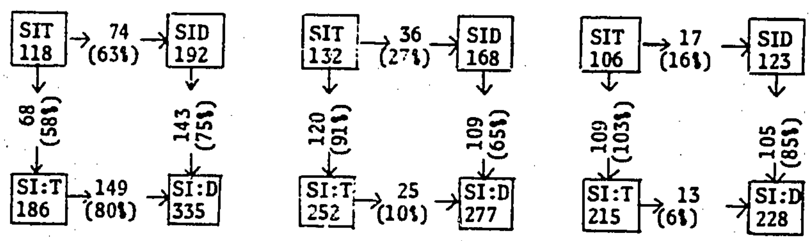
*The duration of the silent interval and voicing of the word final stops.* – With regard to the parameter SI the groups do not seem to differ from each other in any essential way: for each group the /fortes/ have a somewhat longer SI than the /lenes/, a difference that is statistically strongly significant for each group. The VD (average of the three vowel classes) and SI data are presented graphically in Chart 6. It will be remembered from above that in the word medial stops group *Engl.* showed no

CHART 6. The durations of the preceding vowel (VD) and silent interval (SI) of the word final stops. The units on the time scale are milliseconds; *f* and *l* stand for the categories /fortis/ and /lenis/, respectively.



CHARTS 7-9. Summaries of the effects of the two factors influencing the parameter VD or the duration of the vowel preceding a word final stop. The downward arrows: the lengthening of the /tense/ vowels compared to the /lax/ ones; the left-to-right arrows: the lengthening of the pre-/lenis/ stops compared to the pre-/fortis/ ones. The units are milliseconds or (in parentheses) per cent values. The letters I: and I stand for /tense/ and /lax/ vowels and the letters T and D for /fortis/ and /lenis/ stops, respectively.

CHART 7. Group *Engl.* CHART 8. Group *S2.* CHART 9. Group *S1.*




consistent differences in the SI parameter with regard to the /fortis/-/lenis/ distinction. One possible explanation to this discrepancy between the two positions could be that the consonant/vowel ratio is important for cueing the distinction in the word final position and that the differences in the duration of the silent interval of the stop are "needed" to contribute to the differentiation of these ratios. In the case of word initial or word medial stops aspiration (which is laryngeally controlled) takes care of differentiating the two categories, but in word final stops (especially when these are at the same time utterance final or followed by other obstruents) aspiration cannot operate this way, at least not if aspiration is understood (following Kim 1970) to be a delay in the onset of voicing of the following sonorant. It is conceivable, however, that aspiration could operate indirectly, i.e. through the friction that inevitably accompanies the release of aspirated stops, but then many utterance final stops are unreleased. Thus the function elsewhere served by aspiration could in this position be taken up by the potentially available differences in closure duration. With regard to the physiological mechanisms involved it may already be pointed out that the noted differences in the SI values of the two categories for group *Engl.* have the important implication that the /fortis/-/lenis/ distinction can at least in certain environments be produced by variations in the timing of supraglottal articulations alone, i.e. without the participation of the larynx, which for the native group seemed to be responsible for the realization of the distinction at least in the word medial position. This point will be further elaborated below.

Much the same observations are valid for the extent of voicing or EV in the word final position as in the other two positions. Thus group *S1* has the least and group *S2* the most extensive voicing of the /lenes/, although the differences between the latter group and group *Engl.* are negligible in this respect. The absolute EV value is also naturally dependent on the value of the parameter SI. With regard to the /fortes/ we see again that those of group *Engl.* are completely voiceless while both Finnish groups show occasional voicing. Although numerically small, these differences are important indices of differences in the production of these sounds, especially with regard to laryngeal activity.

*The effect of the place of production.* — The data on the word final stops have been reorganized in Tables 49-51 (the /fortes/) and 52-54 (the /lenes/) to bring out the influence of place of articulation on the relevant parameters. As these data cannot as yet be used to explain the /fortis/-/lenis/ difference they will be published for the benefit of anyone interested in place differences *per se*, without any comments from the writer. In Chart 10 below all and only the statistically significant trends observed in the parameter SI of the material have been tabulated for each group. Only the *direction* of the order of magnitude is shown, a comma indicating that the two phonemes separated by it do not differ from each other statistically with respect to the parameter SI.

CHART 10. The order of magnitude of the SI of the word final stops

| Group | The word final /fortes/ | The word final /lenes/ |
|---|---|---|
| *Engl.* | /p/ > /k/ > /t/ | /b/ > /g/ > /d/ |
| *S2* | /p/ > /t/, /k/ | /b/ > /d/, /g/ |
| *S1* | /p/ > /k/ | /b/ > /d/ |

Tables 49-51. The effect of the place features /labial/, /alveolar/ and /velar/ on the parameters VD, SI and EV of the word final /fortes/.

Table 49. Group *Engl.*

| | /labials/ | | | /alveolars/ | | | /velars/ | | | differences of means | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_a$ | $s_a$ | $N_a$ | $\bar{X}_v$ | $s_v$ | $N_v$ | $\bar{X}_l-\bar{X}_a$ | $\bar{X}_l-\bar{X}_v$ | $\bar{X}_a-\bar{X}_v$ | $P_{l-a}$ | $P_{l-v}$ | $P_{a-v}$ |
| VD | 132 | 26 | 60 | 174 | 55 | 80 | 150 | 58 | 70 | -42 | -18 | 24 | **** | * | ** |
| SI | 119 | 17 | 60 | 91 | 24 | 80 | 101 | 19 | 70 | 28 | 18 | -10 | **** | **** | **** |
| EV | 0 | 0 | 60 | 0 | 0 | 80 | 0 | 0 | 70 | 0 | 0 | 0 | non | non | non |

Table 50. Group *S2.*

| | /labials/ | | | /alveolars/ | | | /velars/ | | | differences of means | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_a$ | $s_a$ | $N_a$ | $\bar{X}_v$ | $s_v$ | $N_v$ | $\bar{X}_l-\bar{X}_a$ | $\bar{X}_l-\bar{X}_v$ | $\bar{X}_a-\bar{X}_v$ | $P_{l-a}$ | $P_{l-v}$ | $P_{a-v}$ |
| VD | 120 | 53 | 60 | 192 | 68 | 80 | 193 | 66 | 70 | -22 | -23 | -1 | * | * | non |
| SI | 124 | 18 | 60 | 115 | 24 | 80 | 106 | 30 | 70 | 9 | 18 | 9 | ** | **** | * |
| EV | 8 | 15 | 60 | 0 | 3 | 80 | 1 | 9 | 70 | 8 | 7 | -1 | **** | **** | non |

Table 51. Group *S1.*

| | /labials/ | | | /alveolars/ | | | /velars/ | | | differences of means | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_a$ | $s_a$ | $N_a$ | $\bar{X}_v$ | $s_v$ | $N_v$ | $\bar{X}_l-\bar{X}_a$ | $\bar{X}_l-\bar{X}_v$ | $\bar{X}_a-\bar{X}_v$ | $P_{l-a}$ | $P_{l-v}$ | $P_{a-v}$ |
| VD | 139 | 53 | 60 | 161 | 68 | 80 | 153 | 65 | 70 | -22 | -14 | 8 | * | non | non |
| SI | 114 | 36 | 60 | 104 | 36 | 80 | 100 | 40 | 70 | 10 | 14 | 4 | non | * | non |
| EV | 5 | 11 | 60 | 1 | 6 | 80 | 0 | 2 | 70 | 4 | 5 | 1 | *** | **** | non |

Tables 52-54: The effect of the place features /labial/, /alveolar/ and /velar/ on the parameters VD, SI and EV of the word final /lenes/.

Table 52. Group *Engl.*

| | /labials/ | | | /alveolars/ | | | /velars/ | | | differences of means | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_a$ | $s_a$ | $N_a$ | $\bar{X}_v$ | $s_v$ | $N_v$ | $\bar{X}_l-\bar{X}_a$ | $\bar{X}_l-\bar{X}_v$ | $\bar{X}_a-\bar{X}_v$ | $P_{l-a}$ | $P_{l-v}$ | $P_{a-v}$ |
| VD | 201 | 45 | 50 | 272 | 67 | 85 | 210 | 56 | 45 | -71 | -9 | 62 | **** | non | **** |
| SI | 91 | 18 | 50 | 63 | 13 | 85 | 80 | 17 | 45 | 28 | 11 | -17 | **** | **** | **** |
| EV | 71 | 31 | 50 | 43 | 21 | 85 | 65 | 25 | 45 | 28 | 6 | -22 | **** | non | **** |

Table 53. Group *S2.*

| | /labials/ | | | /alveolars/ | | | /velars/ | | | differences of means | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_a$ | $s_a$ | $N_a$ | $\bar{X}_v$ | $s_v$ | $N_v$ | $\bar{X}_l-\bar{X}_a$ | $\bar{X}_l-\bar{X}_v$ | $\bar{X}_a-\bar{X}_v$ | $P_{l-a}$ | $P_{l-v}$ | $P_{a-v}$ |
| VD | 170 | 36 | 50 | 217 | 58 | 85 | 188 | 35 | 45 | -47 | -18 | 29 | **** | ** | *** |
| SI | 105 | 16 | 50 | 82 | 20 | 85 | 86 | 27 | 45 | 23 | 19 | -4 | **** | **** | non |
| EV | 89 | 35 | 50 | 49 | 33 | 85 | 58 | 36 | 45 | 40 | 31 | -9 | **** | **** | non |

Table 54. Group *Sl.*

| | /labials/ | | | /alveolars/ | | | /velars/ | | | differences of means | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\bar{X}_l$ | $s_l$ | $N_l$ | $\bar{X}_a$ | $s_a$ | $N_a$ | $\bar{X}_v$ | $s_v$ | $N_v$ | $\bar{X}_l-\bar{X}_a$ | $\bar{X}_l-\bar{X}_v$ | $\bar{X}_a-\bar{X}_v$ | $P_{l-a}$ | $P_{l-v}$ | $P_{a-v}$ |
| VD | 124 | 36 | 50 | 165 | 60 | 85 | 125 | 29 | 45 | -41 | -1 | 40 | **** | non | **** |
| SI | 108 | 36 | 50 | 87 | 29 | 85 | 97 | 30 | 45 | 21 | 11 | -10 | **** | non | non |
| EV | 18 | 24 | 50 | 14 | 18 | 85 | 17 | 29 | 45 | 4 | 1 | -3 | non | non | non |

# A SURVEY OF THE PHYSIOLOGICAL CORRELATES OF THE FORTIS/LENIS DISTINCTION

## GENERAL CONSIDERATIONS

The physiological investigation of the /ptk/-/bdg/ distinction has, at least to a great extent, been prompted by the current goal of phonetic research to find, at some level of speech production above that of acoustics, context-independent, invariant correlates of the linguistically relevant units, the distinctive features. Thus it is believed that in spite of the largely context-dependent acoustic output variation, the distinctive features would at some higher level always be represented by invariant units, and that the great variations in the acoustic output forms would be the result of automatic peripheral constraints, mechanical, aerodynamic and otherwise. So far the results of trying to find the physiological level corresponding to the linguistic one in a one-to-one relation, with each distinctive feature always represented in the same way, have been negative; at least nothing like conclusive findings have been obtained (for a recent summary of various motor control mechanisms the reader is adviced to Lindblom (1974) and the references therein). It may be noted in this context that descriptive labels such as *voiceless-voiced*, *fortis-lenis*, *tense-lax* etc. sometimes imply the existence of such a level (although the labels /fortis/ and /lenis/ used in this study are not meant to make any *a priori* claims about the realizations of the sounds in concrete utterances).

According to the widely accepted myoelastic theory of phonation vocal cord vibration takes place roughly in the following way; in preparation of speech, the vocal cords are pulled together to a position appropriate for voicing, just prior to the initiation of speech (see for example Ladefoged 1973: 73-83). Then, provided that the air flow through the glottis is sufficiently strong, the Bernoulli effect will cause the vocal cords to vibrate spontaneously, without any further innervation of the larynx musculature. Thus, with some amount of simplification, we can say that two conditions are necessary for voicing to occur in speech, namely the appropriate positioning of the vocal cords *and* a sufficiently free passage of air through the vocal tract. In sonorants, which have a relatively free passage of air, either through the mouth or the nose, or both, the air flow across the glottis is normally sufficient for the Bernoulli effect to take care of voicing, and it is a well-known fact that the sonorants are in the overwhelming majority of cases fully voiced. In the production of obstruents, on the other hand, the situation is different. They are produced with a radical hindrance to the air flow and consequently the pressure drop across the glottis (i.e. the difference between subglottal and supraglottal or intraoral air pressures soon diminishes during the occlusion so as to render spontaneous vocal cord oscillation impossible. In other words, during the production of obstruents one of the prerequisites of voicing, namely the free passage of air, is absent, as due to the levelling of the air pressures below and above the glottis the air flow will rapidly slow down and eventually stop altogether. Thus the myoelastic (or "tonic", see e.g. Gimson 1966: 8) theory of phonation, in its simplest form, predicts that, given the glottal configuration proper for speech, voiceless stretches of the speech wave are conditioned and caused by radical constrictions in the upper articulatory tract.

In accordance with the above theoretical considerations (which will be discussed in more detail below) one of the aims of concrete research work has been to find mechanisms that would help maintain voicing during the production of English /bdg/ which, according to the theory sketched above, would without any extra adjustments be normally voiceless. On the other hand, the theory would not necessarily predict any such extra adjustments for the production of /ptk/, but it would neither explain the strong aspiration usually accompanying English /ptk/, and therefore another goal of research has been to find the origin of the aspiration. The relations between these theoretical predictions and the phonetic properties of concrete sounds will be discussed more thoroughly in connection with the markedness theory below (in section The Fortis/Lenis Distinction and the Theory of Markedness).

Next, data found in the literature on the different physiological parameters supposedly responsible for the observable acoustic differences between the realizations of /ptk/ and /bdg/ will be presented.

## SUBGLOTTAL AIR PRESSURE

According to Gimson (1966: 32), the /fortes/ are distinguished from the /lenes/ (in addition to voicing differences) by "the degree of breath and muscular effort involved in the articulation"; when the voice opposition (i.e. the difference between physically voiced and voiceless stops) is neutralized "the energy of articulation" becomes an important factor. "Breath"can most probably be equated with subglottal pressure (i.e. the pressure of the air in the lungs), and the reasoning is very clear: aspiration is defined by Gimson (1966: 146) as an interval of strongly expelled breath between the release of the occlusion and the onset of the following vowel, and it is not difficult to imagine that this strong expulsion should be caused by heightened subglottal pressure. A similar conception of aspiration is held and the same feature (i.e. heightened subglottal pressure) is invoked by Chomsky and Halle (1968: 326). Neat and elegant as the explanation may seem, experimental evidence showing that the subglottal pressure is indeed higher for the /fortes/ is not available, and the relevant reports found in the literature all indicate that this feature is not used to signal the /ptk/-/bdg/ distinction. Thus for example Netsell (1969), using three speakers of American English as subjects, has taken simultaneous recordings of subglottal and supraglottal (=intraoral) air pressures and comes to the conclusion that the respiratory system generates an essentially invariant driving pressure with regard to the /fortis/-/lenis/ distinction. Without going into unrelevant details, it may be pointed out that similar results have been obtained for example by Ladefoged (1967), Lieberman (1967), Slis (1970) and Shipp (1973). Thus there are strong grounds for concluding that the origin of the differences connected with the distinction is not due to the activity of the lungs.

SUPRAGLOTTAL (INTRAORAL) AIR PRESSURE

The measurements of intraoral air pressure show invariably higher values for /ptk/ than for /bdg/ (see for instance Malécot 1968; Netsell 1969; Lubker and Parris 1969; Lisker 1970; Slis 1970; Shipp 1973). Disregarding any differences in the glottal state between /ptk/ and /bdg/ it could be hypothesized that the observed differences were due to the (active) enlargement of the oropharyngeal cavity during the occlusion of /bdg/ (for discussion and data see pp.57-60 below) which, *ceteris paribus*, would result in a higher intraoral air pressure in /ptk/ as in their production no such increase in the volume of the oropharyngeal cavity takes place. However, the observed differences are far too great to be explainable by such an enlargement only, although it inevitably contributes its own share to the difference. By far the most important reason for the pressure differences is the operation of the glottis. In /ptk/ the glottis is wide open (for discussion and data see pp. 60-62 below) whereas in /bdg/ it is in the position appropriate for voicing, i.e. the vocal cords are close to each other (see for example Ladefoged 1973). In /ptk/, due to the abduction of the vocal cords, the passage from the lungs to the mouth becomes instantaneously open and the intraoral air pressure soon becomes approximately equal to the pressure in the lungs which of necessity is somewhat higher than the atmospherical one. In /bdg/, on the other hand, the glottis acts as a kind of valve, letting only small quantities of air pass into the mouth at a time (they may even be small enough to be effectively compensatable by the active enlargement of the oropharyngeal cavity), and the intraoral air pressure may not reach the level of the subglottal air pressure before the release of the closure.

Thus, although a reliable index of the /ptk/-/bdg/ distinction, the intraoral air pressure is not an independent parameter but rather an automatic consequence of other, mainly laryngeal, parameters.

MUSCULAR TENSION

Under this heading various articulatory measures will be subsumed, all of them at least in part concerned with some aspect of the supraglottal articulators.

The second property, according to Gimson (1966; 32, 146), that distinguishes /ptk/ from /bdg/ is the greater muscular effort in the production of the former. According to Jakobson, Fant and Halle (1955: 38) "tense phonemes (e.g. /ptk/, K.S.) are articulated with greater distinctness and pressure than the corresponding lax phonemes. The muscular strain affects the tongue, the walls of the vocal tract and the glottis. The higher tension is associated with a greater deformation of the entire vocal tract from its neutral position. This is in agreement with the fact that tense phonemes have a longer duration than their lax counterparts. The acoustic effects due to the greater and less rigidity of the walls remain open to question." (The glottis will be discussed in the next section; it may be noted here that the terms "tense" and "lax" are more often than not restricted to refer to supraglottal properties only.) As regards the possible tenseness of the upper vocal tract, the present writer fails to see its (supposedly obvious) connection with a longer duration. Duration should be regarded as a parameter independent of tenseness if the latter is understood to refer to different *states* of the musculature (a *state* being capable of existing varying lengths of time). Incidentally, if the rigidity of the walls has no audible effects on the speech wave its efficiency in signalling the /ptk/-/bdg/ distinction is at least questionable.

Malécot (1966) has studied the mechanical pressures exerted during stop occlusion in American English. According to his measurements there are no very significant differences between the two categories of stops in this respect. According to Lubker and Parris (1970: 625) the labial gesture for /p/ and /b/ is essentially monotypic, requiring no more forceful labial contact for one than for the other. Similarly Kent and Moll (1969: 1555) conclude that homorganic stop and nasal consonants are produced with a common gesture of the constrictory articulator.

EMG (electromyographic) measurements have also been performed during the production of labial stops. Again Lubker and Parris (1970: 625) report of no consistent differences in EMG activity of the lips between /p/ and /b/. Instead, they emphasize that there is considerable between-subject variability with respect to the various pressure and EMG measures. This probably explains the inconsistency observable between the results obtained in different investigations. Thus Slis (1970; 1971), for example, has found that in Dutch (and this may be another reason for the differences in the results) both the lip-closing and lip-opening EMG activities were significantly higher for embedded /p/ than for /b/. With regard to the great between-subject variability reported by Lubker and Parris (1970) the present writer feels inclined to give less weight to the findings of Slis (who has one, occasionally two subjects against the eighteen of Lubker and Parris and the three of Kent and Moll).

Perkell (1965) has conducted X-ray motion picture studies that indicate a greater pharyngeal cavity width during the articulation of /d/ as compared to /t/. This finding is interpreted by Perkell (and later by Chomsky and Halle 1968: 325) to imply that in the production of /t/ the walls of the vocal tract are rigid as a result of muscular tension (cf. the view of Jakobson, Fant and Halle discussed above), whereas during /d/ the walls are lax and able to expand to permit the increase in volume necessary for voicing to continue during the occlusion. Thus, according to Perkell, the expansion of the pharynx would occur passively, as a result of the vocal tract being compliant. The plausibility of this interpretation will be cricized presently.

Kent and Moll, using cinefluorographic films, found out that /bdg/ are characterized by a lower hyoid bone position and a greater tongue-pharynx width than /ptk/ (Kent and Moll 1969: 1552). It was further ascertained that there was an actual increase in the volume of the supraglottal cavities during /bdg/, whereas there were smaller increases, no increases at all or a slight reduction in cavity size during /ptk/. However, the authors prefer the explanation that pharyngeal expansion during the voiced stops could occur as the result of an active mechanism (p. 1554). They point out that the changes in vocal tract compliance proposed by Perkell are not very likely in view of the fact that the intraoral pressure is everywhere reported to be higher for /ptk/ than for /bdg/ (for data see pp. 56-57 above). With regard to the intraoral pressure alone, then, one would rather expect the pharynx walls to be wider apart and the oropharyngeal cavity volume to be larger in /ptk/ and *not* in /bdg/ as the intraoral pressure is much higher in the first series. At the same time, the tensing of the cavity walls during the occlusion of /ptk/ resulting in a smaller volume of the oropharyngeal cavity would have to be so strong as to offset the expanding influence of the higher intraoral pressure. On the whole Kent and Moll interpret their data to offer further support for the primacy of glottal activity in making the /ptk/-/bdg/ contrast.

The only reliable physiological difference between /ptk/ and /bdg/ so far discussed seems to be that in the latter a depression of the larynx occurs together with a depression of the hyoid bone, both of which cause a lengthening of the oropharyngeal cavity and a gradual increase in supraglottal volume during the closure period. It is possible that these depressions depend on the activity of extrinsic laryngeal muscles (see Iivonen 1972: 45; and Kent and Moll 1969: 1554). It seems most likely that these movements are caused by an active mechanism and it seems reasonable to identify them as the something "extra" presupposed by the myoelastic theory of phonation for the maintenance of favourable conditions for voicing during the occlusion of voiced stops.

Duration of occlusion is another parameter that could be responsible for the contrast. However, no data available seem to indicate any consistent differences in this respect between the two sets (see for example Kent and Moll 1969; Lubker and Parris 1969; Lisker 1972; Suen and Beddoes 1974).

It will be remembered that similar results (although the measurements were not physiological) were also obtained in the present experiment for the native English group (see Table 23 on p. 29 above).

LARYNGEAL MECHANISMS

By now it seems to have been established beyond doubt that some kind of opening activity of the glottis takes place during the occlusion phase of English /ptk/ in most environments, while no such opening takes place during the production of /bdg/ (see for example Lisker, Abramson, Cooper and Schvey 1969; Sawashima, Abramson, Cooper and Lisker 1970; Lisker and Abramson 1971a, 1971b; Hirose and Gay 1972; Ladefoged 1973; Shipp 1973). It has been found that the opening of the glottis takes place especially in prestressed positions, whereas in unstressed positions such opening has not always been observed or it is weaker. In fact it is quite obvious that this glottal opening takes place whenever aspiration occurs, in other words that aspiration is controlled by the opening activity or abduction of the glottis. Lisker, Abramson, Cooper and Schvey (1969) and Sawashima, Abramson Cooper and Lisker (1970) have found out, using transillumination of the larynx in running speech by a fiberoptics system, that the opening of the glottis characterizing the production of /ptk/ is effected by controlling the arytenoid cartilages which are responsible for the opening and closing movements of the glottis. Similar observations for the voiceless, aspirated stops of languages other than English are also numerous, see for example Sawashima and Miyazaki (1973) and Sawashima and Niimi (1974) for Japanese, Kim (1970), Kagaya (1971) and Abberton (1972) for Korean, Slis (1970; 1971) for Dutch, and Lindqvist (1972) for Swedish.

Kim (1970) has studied aspiration mainly using speakers of Korean as subjects but he clearly interprets his results to be valid for other languages as well, and in fact he applies his theory of aspiration to explain certain phenomena of the English language. According to Kim, aspiration is a function of the size of the glottal opening at the time of the release of the oral closure of a stop. Thus, the wider the glottis at the release of the oral closure, the longer the intervening period between the release and the onset of voicing, i.e., the longer the aspiration, assuming a constant rate for the closing movement of the glottis. Aspiration defined in this way can be equated with Lisker and Abramson's positive VOT values, i.e. with a voicing lag. However, Kim's view of the controlling mechanism of the glottal opening is slightly different from that of Lisker and Abramson. According to Kim (1970: 112), the instructions to close the glottis are assumed to be simultaneous for all voiceless stops, different aspiration lengths being due to different degrees of glottal opening. More specifically, stops would have different degrees of glottal opening (e.g. in different contexts) during their occlusion phases, and the instructions to close the glottis for the following vowel would always take place at the same time (relative to the time of the release). The closing rate being constant for all stops (whether it be spontaneous or active), different aspiration lengths would be due to differences in the size of the initial glottal opening. According to Lisker and Abramson, on the other hand, the timing of the instructions to close the glottis is assumed to occur at different times according to the different aspiration lengths desired, and thus they emphasize the importance of the timing difference as a separate, independent physiological mechanism.

Confirmation for Lisker and Abramson's view comes from the electromyographic (EMG) studies of the intrinsic laryngeal muscles in voicing control conducted by Hirose and Gay (1972). They have studied the EMG activity of these muscles in the speech of two American English speakers and found that the posterior cricoarytenoid (PCA) muscle, an abductor causing the arytenoid cartilages (and consequently the vocal cords) to be separated, actively participates in laryngeal adjustments, particularly for the /ptk/-/bdg/ distinction. According to the authors (p. 158), there is a consistent increase in PCA activity for /ptk/ regardless of phoneme environment, and no such activity for /bdg/. It was further found that the interarytenoid (INT) muscle, an adductor causing the glottis to close, had a higher activity during the vowel after a /fortis/ consonant than after a /lenis/ one. The authors state as an explanation that "since glottal width is larger during the articulation of a voiceless consonant than for a voiced consonant, it is reasonable to assume that the activity of the INT, which is responsible for adduction of the vocal cords, should be greater after a voiceless consonant" (p. 159). The activity of the INT muscle in both cases seems to indicate that the closing of the glottis does not normally occur passively, which would cause lag times of the order of 120-130 msec. (see Lieberman 1967: 10), but as a result of an active mechanism. Further, the authors conclude (p. 161) that their data support the existence of active muscular control of glottal configuration rather than a mechanism where prevailing glottal conditions modify in different ways gestures organized in the same way (i.e. gestures with simultaneous instructions). In other words, their data "would suggest the ubiquity of an independent timing control mechanisms" (ibid.).

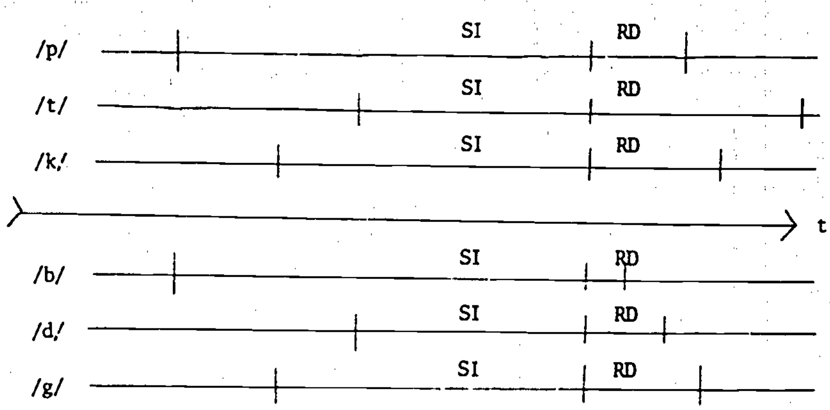
In sum, then, it seems that the most reliable differences correlating with the /fortis/-/lenis/ distinction are to be found in the laryngeal events. Roughly, it seems that the extrinsic laryngeal muscles are connected with the production of /bdg/, enabling the prolonged transglottal flow necessary for voicing by enlarging the oropharyngeal cavity, while activity of the intrinsic laryngeal musculature is characteristic for the production of /ptk/, causing an active devoicing of these sounds.

A SHORT DIGRESSION

In this section a short excursion will be made back to some problems left unresolved in discussing the results of the experiment on pp. 37-43 above. There it was seen (Tables 39 and 44) that the order of magnitude of the release durations (RD) of the word medial /fortes/ and /lenes/ of group *Engl.* are different. It was also seen that the /lenes/ of different places of production have statistically significant differences in their total durations (TD=SI+RD) while no such differences can be observed for the /fortes/. Thirdly, significant differences exist between the places of production with regard to the silent interval (SI) of both categories. It was mentioned (on p. 41 above) that the explanation for these observations is to be found in the temporal coordination between laryngeal and supraglottal activities, and now we are in a position better to understand the mechanisms involved. Below the data concerning the parameters SI, RD and TD of the word medial stops of group *Engl.* are presented in a schematic form. The dimension from left to right is time, and the data are lined up so that the SI-RD borders are at the same point in time. The durations are not represented in their exact proportions.

Consider first the fact that the release durations of the two categories have not the same order of magnitude with respect to place of production. This, the present writer wishes to argue, is because these measures include different phonetic segments in the two cases. In /ptk/, the release duration includes any friction created at the constriction plus the voiceless interval

CHART 11. A schematic representation of the durations of SI, RD and TD of the word medial stops of group *Engl*. The durations are not represented to scale.

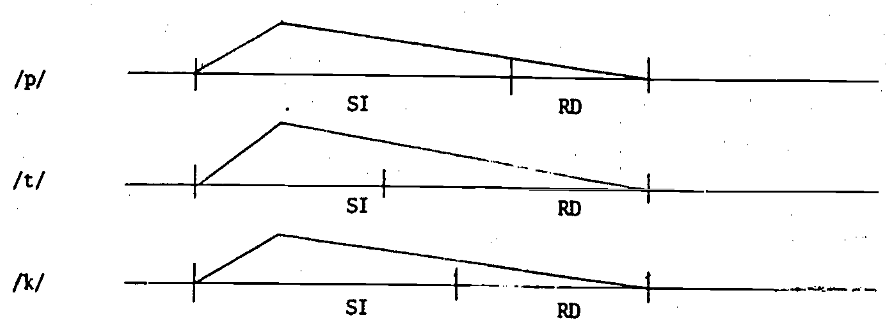



due to aspiration, the latter being longer in extent and containing or "masking" the former. Thus the duration of the RD in the /fortes/ is solely dependent on aspiration. In /bdg/, on the other hand, the RD measure contains only the friction and possibly some short delay in the onset of regular voicing in those cases where there has been a voice break during the occlusion (this occasional voice break and the resultant short delay in voice onset are *passive* responses of the phonatory system to unfavourable *aerodynamic* conditions and thus completely different from aspiration which has its origin in the *active* workings of the glottis). It is quite possible that the frictional characteristics of the homorganic stops of both categories are the same, but being short in duration have been overrun by aspiration in the /fortes/. Further, there are no statistically significant deviations among both categories of the Finnish groups from the order of magnitude of the RD duration observable in the /lenes/ of group *Engl*., this further confirming the view that these regularities reflect universal (*supraglottal*) articulatory constraints (like the occlusion durations of stops of different places of production which were similar for all groups and both categories).

To see why the order of magnitude of the release durations of the /fortes/ is what it is and why there are no significant differences in the total durations of these sounds between different places of production despite such differences in the /lenes/, we need to rearrange the /fortes/ so that for each place of production the beginning of the silent interval is at the same point in time, in the way shown below. Let us in addition draw a steeply rising line, starting from the beginning of the silent interval, to represent the rapid abduction of the glottis away from its voicing position, and then connect a descending line to represent the slower return of the glottis to the voicing position.

From this scheme it can be seen that a similar glottal gesture for each place of production results in different aspiration lengths due to the differences in the durations of the supraglottal occlusions. This single glottal gesture also explains the reciprocality of the SI and RD measures of the /fortes/ mentioned on pp. 41 and 43. For the /lenes/ this glottal levelling of the different occlusion durations is of course not applicable. For lack of information about the durations of the silent intervals of the word initial stops it is not possible to attempt to explain their different RD durations in the same way, although it seems reasonable enough that similar relations also obtain in that position.

CHART 12. A schematic representation of the levelling effect of the glottal abduction gesture on the total durations TD (=SI+RD) of the word medial /fortes/.



WHAT IS ASPIRATION

Aspiration is the voiceless interval between the release of a stop and the onset of voicing of the following sonorant. Although the exact nature of the controlling mechanisms of the opening and closing of the glottis is as yet unknown, it seems to have been established beyond doubt that the opening of the glottis in aspirated stops is a result of an active abduction gesture effected by the arytenoid cartilages. It seems equally well established that no such adjustments of the glottis are operative during the production of voiced stops. It was seen that no experimental validation has been found for the postulation of the feature "heightened subglottal pressure" or the like and that the higher intraoral pressures connected with voiceless aspirated stops were the automatic result of the opening of the glottis and *not* an independent dimension. Thus the "extra puff of air" traditionally connected with aspiration is not the cause of aspiration but rather its effect. As an example of traditional, empirically unmotivated view of aspiration we can take the explanation offered by Sovijärvi (1963: 41) who connects it with the speed at which the articulating organs move apart at the explosion phase of a stop consonant. Thus, according to Sovijärvi, the faster the explosion movement (the movement apart of the organs forming the occlusion), the greater the pressure of air in the cavities behind the occlusion, and further, the aspiration of a stop always presupposes a very quick explosion. This explanation presupposes that the pressure of air behind the occlusion is at its maximum at the very beginning of the occlusion, starting then to decay. This is hardly likely, for it is difficult to imagine how the intraoral pressure could reach the maximum value at once, and in fact actual measurements rather show a steady rise in pressure during the occlusion phase (see for example Netsell 1969; Slis 1970; Shipp 1973).

The greater intraoral air pressure normally accompanying aspirated stops explains why they also normally have a stronger burst of friction at the release (it also motivates the term "burst" used in the classical studies of the Haskins group to include both friction and aspiration). When the occlusion is released there is for a short while a narrow constriction through which the high-pressure air escapes out into the open, and frictional noise is created. However, it is important that the two articulatory distinct but auditively often inextricable phenomena, aspiration and friction, should be kept apart, otherwise important aspects of the production of stop consonants will be overlooked. Friction is produced at the place of constriction (and its spectrum is different in different places of production), while aspiration is the result of a delay in voice onset at the glottis. Whether the absence of voice during aspiration is *per se* the most important cue for the perception of aspiration or whether concomitant properties such as friction at the explosion or the [h]-like friction often heard during the voiceless period also have some cue value is a question that can be settled only by conducting appropriate perceptual tests. The important point here is the fact that they are normally co-occurring facets of the same feature.

Depending on the timing relations within supraglottal articulations and between supraglottal and glottal activities different stops will be produced. Consider for example the differences between the friction durations of English /t/ and the Danish strongly affricated pre-stressed /t/. In both of these the total release durations (from release to voice onset) may be equal, despite the difference in the duration of the friction. If the notions of friction and aspiration were lumped together it would be impossible to describe differences of the above nature.

At one end of the voicing continuum we find the stops in which the vocal cord vibration continues throughout the occlusion phase. These stops can be said to be fully voiced. At the other end of the continuum are the stops in which the whole occlusion phase and maximal durations of the adjoining segments are produced without vocal cord vibration. These stops can be said to be fully voiceless. The voicelessness of the stops extends to the adjoining segments in the form of aspiration. If the stop devoices the preceding vowel the term "preaspiration" is used (in preaspirated stops the abduction of the glottis is anticipated during the production of the preceding vowel). Lindqvist, for example, reports (1972) of frequent cases of preaspirated post-stressed /ptk/ in Swedish. Preaspiration is also known to occur in Gaelic and Icelandic.[1] In the case of the more frequent form of aspiration the voicelessness of the stop extends to the following vowel (or more generally, to the following sonorant). Between these extremes there

[1] The present writer saw also some traces of preaspiration in the mingograms of word medial /fortes/ by some of the native English subjects; however, these findings were not quantified.

are theoretically an infinite number of stops with different degrees of voicing.

It was suggested on p. 50 above that aspiration may not be applicable as a cue in word final positions. It may be worth while to discuss this possibility again in the light of the physiological data presented. Aspiration was defined as the voiceless interval between the release of the stop and the onset of voicing of the following sonorant. For word final stops that are at the same time uttereance final aspiration would, according to definition, be inapplicable as nothing follows that could be devoiced. If we expand the definition a little to make it include all of the consequences of glottal abduction we see that only the strong "puff of air" would conceivably be capable of acting as a cue in this position. Word final /lenes/ in English being often very moderately voiced, the information load carried by the release burst of the final /fortes/ would be very great *if* no other signalling devices were employed. Additionally, it so happens that the word final /fortes/ are often very weakly released and experimental data (see for example Sawashima, Abramson, Cooper and Lisker 1970) indicate that these stops are normally produced with no or very little opening of the glottis. In this light it is not surprising that the duration of the preceding sonorant has assumed a cue function signalling the /fortis/-/lenis/ character of the stop. According to this interpretation the lengthening of sonorants before word final /lenes/ is not conditioned by the glottal mechanisms directly (for example as the extra time needed by the glottis to assume a position appropriate for voiced obstruents suggested for example by Chomsky and Halle (1968: 301) for no evidence for such *glottal* readjustments for /bdg/ has been presented, instead, the results obtained by Raphael (1975) seem to indicate that the durational differences between vowels preceding voiceless and voiced word final consonants are primarily controlled physiologically by motor commands to the muscles governing the articulators which are active in the formation of vowels), but rather indirectly, by the glottal mechanism's failure to do its job in this particular position. (Naturally the above argumentation applies only to the extra lengthening observable in English and not to the minor lengthening observed in various languages, cf. p. 9 above.)

So far no comprehensive, data-based account of the production of the English stops has appeared, something not very surprising in view of the many complexities involved. Perhaps the closest approximations to such accounts are the various phonetic feature systems proposed in the literature, e.g. those of Jakobson, Fant and Halle (1955), Chomsky and Halle (1968), Halle and Stevens (1971), and Ladefoged (1973). However, most of them are based on at least some amount of speculation, and later research has often been able to show that the mechanisms they have postulated either do not exist or work in a different way, as was occasionally seen above. Others, again, treat the English stops rather superficially (so for example Ladefoged 1973, which also contains a critical survey of some other feature systems). Such criticism is also presented by Lisker and Abramson (1971a).

# THE FORTIS/LENIS DISTINCTION AND THE THEORY OF MARKEDNESS

Let us briefly repeat the main tenets of the myoelastic theory of phonation (on which for example Chomsky and Halle's (1968) marking conventions for the "voice" feature are based). According to the theory, two states of the vocal apparatus are favourable to the occurrence of voicing, namely an appropriate position of the vocal cords themselves and sufficient air flow through the glottis. Given these two conditions, voicing will occur spontaneously as a result of the Bernoulli effect. In obstruents the flow of air is severely impeded, and consequently they tend to be voiceless. Thus voiceless obstruents are in an obvious sense more natural or easier to produce than voiced ones in which the vocal cord oscillation has to be "forced".

If a language has no (phonological) /voicing/ distinction, it seems reasonable to assume that the stops of that language are normally voiceless. Further it seems reasonable to assume, in the words of Lisker and Abramson (1971b: 366) that "if a language is 'normal' in this way, then it seems reasonable to suppose that in fact a single glottal mode, that of voicing, is maintained without significant change in utterances of that language, with shifts in mode reserved for para-linguistic effects. The absence of a distinctive voicing feature is then matched by the absence of differential control of the larynx during speech." There is every reason to believe that Finnish is essentially such a language; this point will be given further attention in discussing the Finnish stops below.

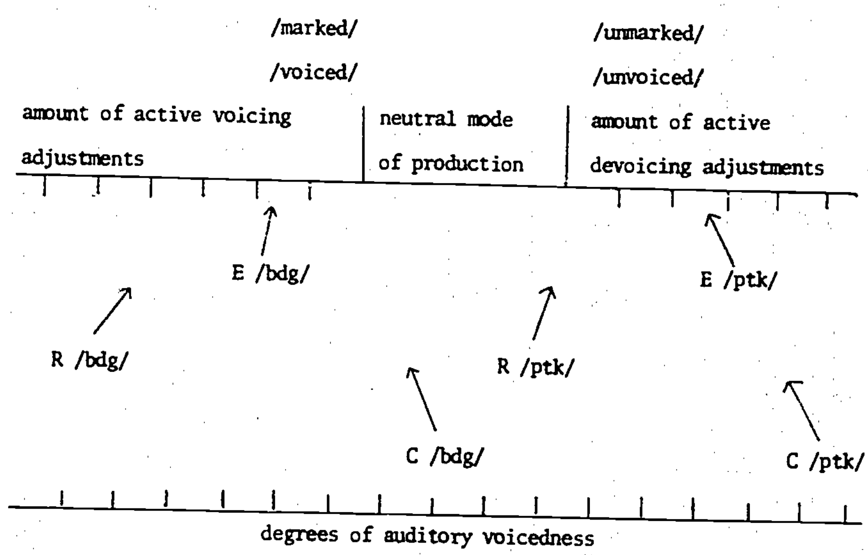
For languages with a /voicing/ distinction, such as English, the theory implies that two distinct modes of stop formation are used by the speakers. The theory does not, contrary to what Lisker and Abramson argue (1971b: 366), imply that languages with a /voicing/ opposition should be rare; instead, it just implies that in such languages the /voiceless/ set is produced in the neutral mode while something "extra" is needed for the /voiced/ set. In this respect the theoretical reasoning of Chomsky and Halle (1968: 300-301) can be considered quite accurate, although they partly rely on features not operative in the distinction (e.g. the heightened subglottal air pressure). In discussing above the two modes of stop production presupposed by the theory the term "two modes" was purposely used instead of the term "two *glottal* modes" used by Lisker and Abramson as the myoelastic theory does not in any way imply that the differences between the productions of voiced and voiceless stops should be locatable to the glottis (and in fact it was seen earlier that for English /bdg/, at least, the adjustments necessary for prolonged voicing took place in the form of a depression of the hyoid bone and the larynx while no adjustments have been found to take place in the glottis).

In Chomsky and Halle's (1968: 400-435) terminology, the /voiceless/ stops, produced in the "neutral" mode, would correspond to the /unmarked/ members of the opposition, whereas the /voiced/ stops, produced with the extra mechanism to maintain voicing during occlusion would correspond to the /marked/ members of the opposition. However, the empirical data available do not seem to fit very neatly into this theoretical framework. For /bdg/ there is no discrepancy, as we have seen, for the depression of the hyoid bone and the larynx can be identified as the special adjustments presupposed by the theory. But /ptk/ are far from being produced in a neutral mode as predicted, it is rather in their production that a "glottal" mode is employed, in the form of the glottal abduction gesture. The data are there on the one hand, and yet we do not feel tempted to discard as false the predictions of the myoelastic theory and of the markedness theory which is based on the observation of the regularities of human language.

To get a wider view of the situation let us make a small comparison between different languages. Let us consider for a moment the phonetic quality of the stops of a few other languages in which a similar phonological opposition between two stops has been postulated. In languages such as French or Russian the voicing of the /voiced/ set of stops is much more extensive than that of English /bdg/; in these languages voicing usually continues throughout the occlusion, also in word initial and final positions. At the same time, the /voiceless/ stops of these stops show almost no traces of aspiration regardless of their position in the word. In comparison of both sets, then, we see that both sets of English stops are shifted towards the unvoiced end of the continuum compared to the French and Russian counterparts. It can at least be hypothesized, for the sake of argument, that the distances on the voicing continuum between the two sets are in each language equal. In Chinese, on the other hand, the /voiced/ set is normally voiceless and unaspirated, the /voiceless/ set being strongly aspirated. Thus both Chinese sets are further to the voiceless end than their English counterparts, respectively. Again we can hypothesize that the separation of the two categories in Chinese is the same as in the other languages mentioned.

The conclusion to be drawn from the above exposition is that languages often use somewhat different means to signal a given phonological distinction. In this concrete case the languages in question occupy different positions on the voicing continuum, relying at the same time on minimal effort to produce sufficient separation of the two categories, also this very typical of human language. If languages would strive after maximal distinctness even at the cost of greater effort we could expect stops like the realizations of French /bdg/ and /ptk/ of Chinese to be used in the same language when, of course, the separation of the categories would be close to maximal. Below the relations between the stops of the languages discussed are presented schematically.

CHART 13. A schematic representation of the stops of English (E), French, and Russian (R) and Chinese (C). The units used on the two phonetic levels are arbitrary.



On the basis of the above scheme it seems that, depending on the language, the stops of either one or the other category demand greater effort on the part of the speaker. Thus, for example, it seems that the /bdg/ of French and Russian are in some way more difficult to produce (i.e. demanding more special adjustments) than the /bdg/ of Chinese, while the /ptk/ of the former languages are "easy" compared to those of the latter.

Assuming that the above scheme contained actual data it is difficult to see how they could be reconciled with the markedness theory without violating one of its basic principles, namely the applicability of the marking conventions in the same way to all languages of the world. If the claim for the universality of the marking conventions were discarded one possible way of handling the situation would be to study all languages with such an opposition separately to assess for each language which of the sets needs more "effort" and then define that set as the /marked/ one for that language. And even more difficult problem is posed by languages with a ternary opposition of the voicing continuum, such as Korean. The kind of procedure mentioned above would correspond closely to demands for phonetic realism in phonological descriptions, a realism which is not present in the above scheme. However, the abandonment of the universality principle would shake the very foundations of the markedness theory.

Another possibility might be to make *ad hoc* rules for the languages that deviate from the general trend. (It is to be noted that at present "the common trend" is taken to be the one predicted by the myoelastic theory of phonation; another way of finding the "natural" category of stops would be to conduct an actual survey of the languages of the world to get statistical information about the frequency of occurrence of different stops. Of course it is quite possible, although perhaps not necessary, that the predictions of the theory would be validated by such a procedure.) In view of these difficulties it is not surprising that Chomsky and Halle say next to nothing about the marking conventions of the voicing feature.

Taken the phonetic quality of English /bdg/ for granted, we could "explain" the *ad hoc* nature of the extra adjustments connected with the production of /ptk/ as a necessity to avoid phonetic overlapping of the stops of the two categories. But how would we explain the phonetic quality of /bdg/? As a result of an *ad hoc* historical sound change?

# THE PROBLEMS CAUSED BY THE ENGLISH FORTIS/LENIS DISTINCTION TO SPEAKERS OF FINNISH

## THE FINNISH STOPS

*Phonological considerations.* – According to taxonomic description there are four stop phonemes in Finnish, namely /ptkd/ (see Karlsson 1969 for a detailed discussion). The marginal status of /d/ is reflected, among other things, by its limited distribution (certain word medial positions), by its nonoccurrence in many dialects and by the fact that in some further dialects it is often realized as a flap rather than a stop. Neither is it, in a generative description, included among the Finnish lexical consonant segments, and its surface representations are the product of morphological rules (Karlsson 1971: 32). If we accept the view (expressed for example by Karlsson 1969: 358) that /d/ is isolated and that there is no stop correlation in Finnish, it is possible to regard Finnish as a language with basically one series of stops, all /unmarked/ for voice (see below for the phonetic differences between (Standard Finnish) /t/ and /d/).

*A phonetic description.* – The kind of experimental data on the Finnish stops relevant here is very scanty, and we have to rely on some occasional observations mentioned in the literature, on theoretical reasoning and on the indirect information obtainable on the basis of the results of the present report.

According to Sovijärvi (1963: 47), /d/ differs articulatorily from /t/ in the following ways: its place of production is more retracted, it is voiced and media, and the larynx is lowered during its production. It is not clear what the feature "media" is supposed to contribute to the phonetic quality of /d/. The difference in place of articulation is also mentioned by Wiik (1965: 24), as well as the shorter duration of /d/ against that of /t/. Lehtonen's (1970: 71) measurements, despite the fact that he has calculated the total durations (i.e. silent interval plus possible release duration) of Finnish plosives, confirm that the occlusion of /d/ is much shorter than that of /t/. These findings seem to indicate that the /t/-/d/ distinction in Finnish is signalled by parameters different from those used in English (for example, it will be remembered from above that no significant differences in the durations of the occlusions of English word medial /t/ and /d/ have been observed). In fact Wiik (1965: 24) mentions the difference in F2 locus (resulting from a difference in the place of the occlusion) as the most important distinctive feature of the /t/-/d/ opposition.

As for the Finnish /pt[illegible] [illegible]ärvi (1963: 39) says that they are produced with an open glot[illegible] [illegible]ut i[illegible] is not clear on what kind of data the contention is based. I[illegible] [illegible]ere are strong reasons for not accepting this view. In the first place, Iivonen's glottographic investigations (1975, and personal communication) show no appreciable differences with regard to glottal opening between the stops and sonorants, although they confirm that /d/ is voiced (the slight opening of the glottis during the fricatives observable in Iivonen's data can be explained as a means of maintaining sufficient air flow for the generation of turbulence during these sounds). The second contention against Sovijärvi's view is based on the fact that the Finnish stops are normally unaspirated (see for example Lehtonen 1970: 51) which indicates that the glottis could not be open to any significant extent at the time of the release. The third kind of evidence (which is connected with the second) derives from the fact that the Finnish /ptk/ often, especially medially between vowels, become partly or even fully voiced. This could not be possible if the vocal cords were not in the position appropriate for voicing, i.e. approximately closed (see for example Ladefoged 1973: 73-76). If they are virtually in this position during the occlusion then at least one of the conditions for spontaneous voicing is always fulfilled, and occasional voicing of /ptk/ could be explained as a result of additional and coexisting favourable aerodynamic conditions prevailing in the vocal tract, e.g. due to incomplete oral closures in rapid, informal speech. Also Iivonen's glottograms mentioned above show that voicing in /ptk/ continues some time after the beginning of the oral closure and starts again immediately after the release. This would be highly unlikely if the glottis were open during the occlusion.

As a summary of the above discussion we can conclude that although both English and Finnish have a series of phonologically /voiceless/ stops the latter are not phonetically very good substitutes for the former. In fact both series of English stops demand some kind of adjustments unfamiliar to the Finnish language, in which the only full series /ptk/ seem to be produced in a neutral mode in which the voice characteristics of segments are conditioned by aerodynamic factors. In other words, the phonetic quality of Finnish stops is somewhere between those of the two English sets.

## A SUMMARY OF THE LEARNING PROBLEMS

Here the major differences found between the productions of the English stops by the three groups *Engl.*, *S2* and *S1* will be briefly summarized and some of the physiological mechanisms involved discussed. Before doing this it may be pointed out that the differences due to place of production observed in the various parameters were generally similar for all groups and need not be mentioned here as they are not likely to cause problems to language learners although they have their interest for the phonetician. There is, however, a single important exception, namely the word medial (intervocalic) /d/ of both Finnish groups which has a considerably shorter silent interval than their /t/. For the English group the silent intervals of these sounds are the same, i.e. different cues are used in English.

Among the differences between the Finnish and the English groups relatable to the voicing dimension the following are the most important: rather poor separation of the /fortis/ and /lenis/ categories by the less advanced group *S1* with regard to the parameters EV (extent of voicing) and RD (release duration) in the word initial and medial positions together with large standard deviations (s) indicating irregularities especially in the production of /bdg/; exaggeration of separation of the categories /fortis/ and /lenis/ by group *S2* in all three positions examined by excessive EV and RD durations (exceeding the "model" durations exhibited by the native English group); and the occasional partial voicing of the /fortes/ by the Finnish groups in all three positions examined against no voicing of the /fortes/ by the English group.

Common to the above mistakes made by the Finnish speakers is that they are caused by varying degrees of inability to shift away from the neutral mode of stop production. For /bdg/ this means that speakers of Finnish are unable to control properly the adjustments (probably effected by extrinsic laryngeal muscles) necessary for maintaining the appropriate transglottal air flow to get the right amount of voicing needed for English /bdg/ (the

Finnish speakers had either too much or too little voicing). For /ptk/ the mistakes indicate that the Finnish speakers are not able to control the devoicing gesture (effected by intrinsic laryngeal muscles) necessary to secure the voicelessness of English /ptk/ (the glottis was open for too long during /ptk/ (group *S2*) or it was in the voicing position during /ptk/ resulting in voice (both groups)). It is interesting in this connection to note that Hirvonen (1970: 80) remarks that "to learn the English rising intonation, then, the Finnish learner needs to acquire a new mechanism for controlling his laryngeal vibrations." For a detailed discussion on the interaction of pitch and voice features see Ladefoged (1973).

The effect of the /fortis/-/lenis/ character of the word final stops on the duration of the preceding vowel is not controlled by laryngeal events. Here the mistake of the Finnish speakers was a total (group *S1*) or partial (group *S2*) failure to use the lengthening of the preceding vowel as a cue for the /lenis/ feature of the word final stop (see pp. 47-48).

Conn ed with the above variations of vowel durations are those caused by the /tense/-/lax/ (or /long/-/short/) character of the vowel itself (at least for a Finn in whose own language such variations are used to signal different things). The mistake made here was the identification of the English /tense/-/lax/ distinction with the partly similar distinction of /double/ and /single/ vowels in Finnish and the resultant excessive lengthening of the /tense/ vowels compared to the /lax/ ones (see pp. 43-47).

# CONCLUSION

## THE ROLE OF INSTRUMENTAL PHONETICS IN CONTRASTIVE ANALYSIS

The experimental procedures and their results discussed above, although rather preliminary in many ways, yet seem to justify and emphasize the importance of concrete instrumental phonetic research as a complement to a phonological contrastive analysis of the native and target languages of the learner. Thus some of the systematic differences in the productions of the relevant sounds by the native English and the Finnish informants were such that they could not have been predicted on the basis of purely phonological considerations. Although not necessarily crucial to the success of communication, these differences should nevertheless be regarded as possible sources of misinterpretation. In real-life communication the listener uses *all* the information available to him to decode a message, a fact that is in danger of being forgotten if the terms used in phonology (e.g. "the minimal distinction", "the distinctive feature" etc.) are too straightforwardly translated onto the level of the actual processes taking place in speech production and perception. It is these actual processes that instrumental phonetics purports to clarify.

It has been seen above that a single phonological, classificatory distinctive opposition manifests itself physically in a number of ways, all contributing their share to signal the distinction. At this concrete level it is meaningless to talk about "distinctive" and "redundant" features, or to lean too heavily on the dichotomy "phonemic mistakes" - "phonetic mistakes", First of all, although it seems evident that some kind of feature detection does take place in speech perception it is the same time equally evident that these detectors do not operate on units of the size of the distinctive features now in use in phonology. Until more is known about the size and function of these units it seems advisable to regard every physical parameter as potentially capable of being used by the listener in making decisions about the linguistic content of a message. And it is obvious that the listener makes his decisions on the basis of the sum of all perceptual cues available rather than concentrating on just one of them and discarding the rest as "redundant" (i.e. as having no information value). We can picture speech recognition as a process where each perceptual feature (whatever their size may be ) is given a scalar value indicating the strength for its "vote" for /feature X/, and the sum effect of all these "votes" of the feature detectors is then compared to other, non-auditory data available, such as higher-level redundancy and context. Only after all these comparisons have been performed has the message been decoded and the segments recognized. Thus we see that the recognition of sound segments is no simple *yes-no* process suggested by the terms "phonemic" and "phonetic mistakes", and that the division of pronunciation errors (which we very frequently make in speaking a foreign language) into one of the classes is done by the hearer only partly on the basis of matters pertaining to the acoustic information and thus to the pronunciation by the speaker. Thus, depending on the force of higher-level redundancies and context we can recognize a segment right at one occasion, despite the "foreign accent" of the speaker (who, we say, has made a "phonetic" pronunciation error), and recognize a similar segment wrong in the absence of any other cues than the auditory ones at another occasion (when we say that the speaker has made a "phonemic" pronunciation error). The division of pronunciation errors into "phonemic" and "phonetic" ones is done on the basis of a complex of coexistent acoustic, linguistic and contextual cues, all affecting the decision of the hearer, and consequently the terms are no very good description of the pronunciation of the speaker. The terms can be used, but only with an understanding that their difference is scalar and relative rather than binary and absolute, and that they are measures of the behaviour of the hearer and not of the speaker.

A NOTE ON TRANSCRIPTION

A conventional juxtaposition of the stop systems of English and Finnish (as for purposes of contrastive analysis) would in all likelihood look something like the following (this is essentially the kind of practice followed for example in the studies in the Contrastive Structure Series, published by the University of Chicago Press under the general editorship of Charles A. Ferguson):

| | English | | | Finnish | | |
|---|---|---|---|---|---|---|
| | labial | alveolar | velar | labial | alveolar | velar |
| voiceless | /p/ | /t/ | /k/ | /p/ | /t/ | /k/ |
| voiced | /b/ | /d/ | /g/ | | (/d/) | |

Now what are some of the (intentional or unintentional) implications of such a juxtaposition for someone not very well acquainted with the conventions of phonological descriptions (e.g., an average language learner)? At least the following three are likely:

a) both languages have voiceless stops
b) only English has voiced stops (disregarding Finnish medial /d/)
c) as a corollary of the above two points, English /ptk/ (and to a certain extent also /d/) are "easy" for Finnish speakers, while /bdg/ are "difficult".

Implication c) above is a result of "mixing the levels", i.e. of translating classificatory features to phonetic ones in too straightforward a manner. A linguistic, however, knows (and the results of this study, among others, confirm) that the terms *voiced* and *voiceless* are used in tables like the above one in a more or less classificatory function, i.e. to denote collectively those phonetic parameters that differentiate /ptk/ and /bdg/. The results of this study also show that *both* series of English stops cause difficulties to speakers of Finnish, and more specifically that the stops of group *S1* (who presumably follow the rules of Finnish stop formation more closely than group *S2*) tend to scatter around values *between* those of /ptk/ and /bdg/ of group *Engl.* with regard to most of the parameters.

Rather, it is the existence in English and nonexistence in Finnish of a phonological opposition between the two series of stops that is the decisive factor here. The lack of such an opposition in Finnish means that the scope of variation produced and tolerated for the Finnish stops is very wide and that the phonetic quality of these sounds tends to approximate that of maximally "neutral" (with respect to ± voicing) or natural stops. The results obtained and the physiological survey show that neither series of English stops are similar to the Finnish ones, despite the fact that both Finnish /ptk/ and English /ptk/ are, in the generative-transformationalist sense of the word (see for example Chomsky-Halle 1968 and Postal 1968), /unmarked/ for voice.

It would be possible to attempt to devise a form of broad transcription that would show the differences between the English and Finnish stops and at the same time indicate explicitly the major allophonic variations connected with the English /ptk/-/bdg/ distinction. Below a set of principles are given according to which such a transcription would deviate from the usual phonemic one. They could be tested for their ability to convey to Finnish learners the major durational variations connected with the distinction. At least they would have the advantage that their appearance in textbooks would force teachers to explain them and thus consider the durational variations.

The suggestions are the following:

a) in the positions where aspiration is operative in English /ptk/ (i.e. next to a primary-stressed vowel except in the word final position) they could be transcribed as [$p^h$, $t^h$, $k^h$]. This would also emphasize to the Finnish learner their difference from Finnish /ptk/.

b) elsewhere (i.e. word finally and next to non-primary-stressed vowels) no extra transcript would be used, these being the positions where they least differ from Finnish /ptk/.

c) as no transfer from Finnish takes place in the case of /bg/ and most cases of /d/ and as rather great variations with respect to the extent of voicing of these stops are both produced and tolerated in perception in English no extra transcript is suggested except in connection with word final /bdg/, where they could be transcribed [˙b, ˙d, ˙g] to emphasize the lengthening effect on the preceding sonorant.

d) the durational variations caused by the /ptk/-/bdg/ distinction are in some cases inextricably interwoven with those caused by differences in vowel class, and therefore the suggestions pertain to vowels, too. Thus it is suggested that the "corresponding" /tense/ and /lax/ vowels should be represented by different letters (this is the convention used for example by Wiik 1965), the differences in the letter emphasizing the differences in quality, the difference in duration being expressed by [˙] always following the /tense/ vowels (this is a slight modification of Wiik's suggestion). Below a few examples are given which show the effected of the suggested conventions on the transcription of some English words.

ortography:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| bit | bit | beat | bead | pit | tippet | hat | had |

broad transcription according to the above suggestions:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| [bIt | bI˙d | bi˙t | bi:d | $p^h$It | $t^h$I$p^h$It | haet | hae˙d] |

FUTURE DIRECTIONS

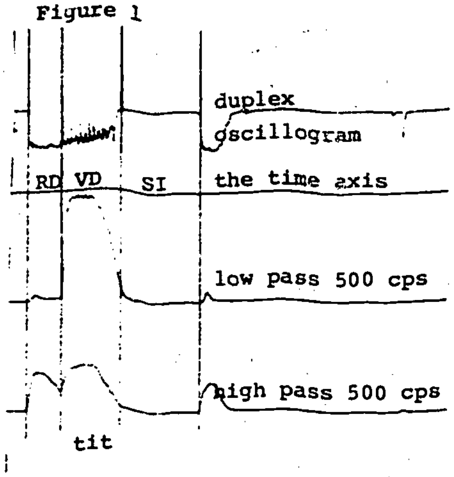
To test at places weakly supported contentions presented in the latter part of this report detailed investigations of the physiological mechanisms involved in the production of both Finnish and English stops should be undertaken. An attempt is also planned to be made to assess the perceptual or cue value of the acoustic differences between the /fortes/ and the /lenes/. This will happen in the form of listening tests where the subjects respond to synthetically produced stimuli with systematically varied acoustic parameters. In this way it may be possible to get valuable information about the differences between native and Finnish speakers of English in the use of various acoustic parameters as cues in the recognition of the /ptk/-/bdg/ distinction. At the same time, it is hoped, it will be possible to determine, at least to some degree, interconnections between speech production and perception, i.e. to determine whether the effective use of a parameter as a cue in perception presupposes its active use in production, or vice versa.

APPENDIX A List of the test words read by the informants.

| | | |
|---|---|---|
| pot | goat | goody |
| tit | peep | bigger |
| cot | tape | back |
| bet | keep | backer |
| dot | deep | bad |
| get | peak | bag |
| pop | teak | baggy |
| top | cake | bat |
| cop | beak | batter |
| dip | dark | dab |
| gap | gawk | dad |
| pick | paid | dagger |
| tick | tide | dapper |
| kick | card | da[illegible] |
| beck | bird | g[illegible] |
| Dick | deed | [illegible] |
| pod | gard | [illegible] |
| Ted | topper | p[illegible] |
| cod | potter | pa[illegible] |
| bed | kicker | paddy |
| dead | cobber | pap |
| god | Teddy | pat |
| pub | Peggy | patty |
| tub | kipper | tab |
| cob | Kitty | tabby |
| bob | picker | tack |
| dub | tubby | tacky |
| gob | toddy | tag |
| pig | piggy | tap |
| tug | dipper | tat |
| keg | gutter | tatty |
| beg | Becky | cab |
| dig | bobby | cabby |
| gig | giddy | cad |
| part | digger | caddy |
| tight | dapper | cap |
| cart | dotty | cat |
| Burt | bicker | catty |
| dart | dubber | kiddy |

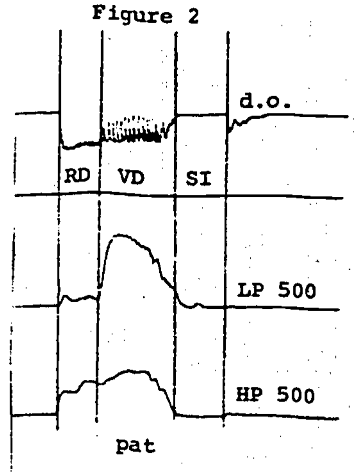
APPENDIX B Figures 1-10. Sample mingograms with examples of the segmentations made.

Figure 1



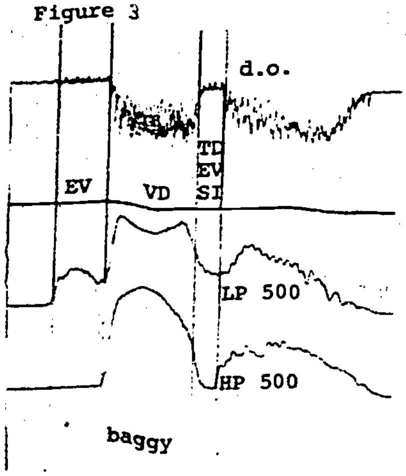

tit

Figure 2



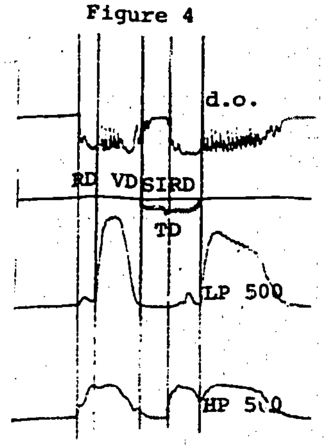

pat

Figure 3



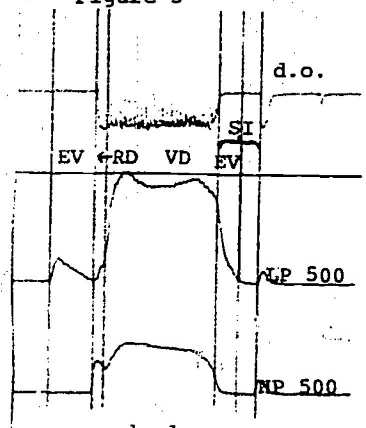

baggy

Figure 4



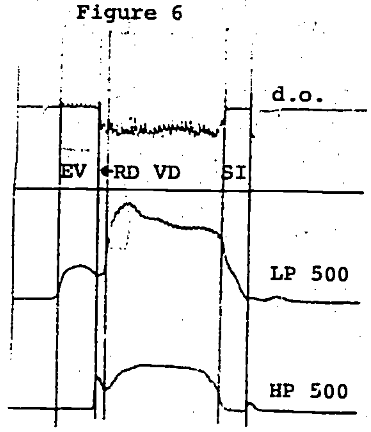

picker

Figure 5



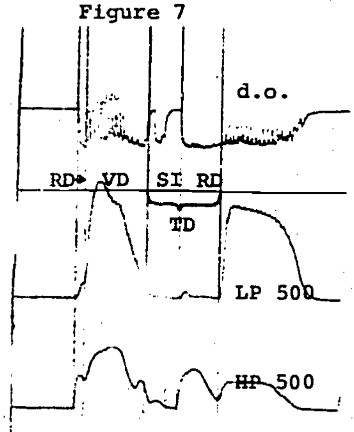

dead

Figure 6



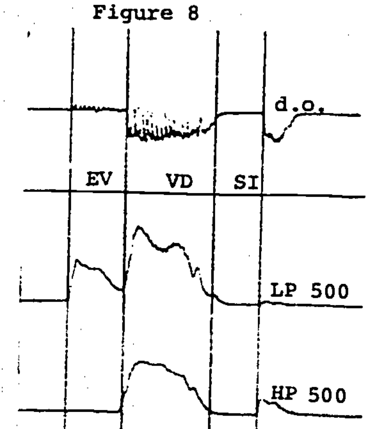

god

Figure 7



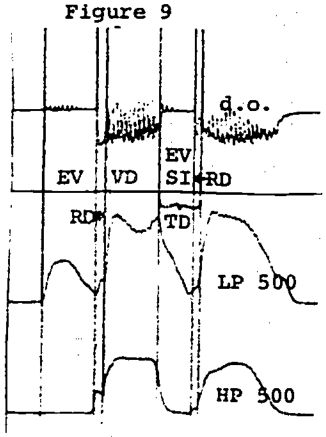

dotty

Figure 8



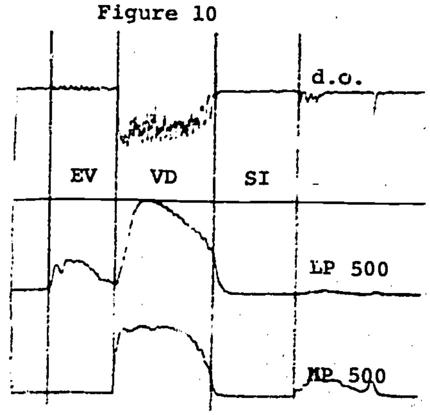

back

Figure 9




dubber

Figure 10




deep

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