

ENGLISH STOPS AFTER INITIAL /s/ *)

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1. Introduction.

After initial /s/ the English stops present difficulties which are both phonetic and phonemic. With the former it is a question of the exact articulation and phonetic properties of these sounds. With phonemics, it is well-known that the opposition between /p,t,k/ and /b,d,g/ is suspended in this position. Thus words like spin, steam, and scold may be interpreted without ambiguity as /spin, sti:m, skould/ as well as /sbin, sdi:m, sgould/. The question is thereby raised as to which of the two phoneme series is realized. In such cases, when from a structural point of view a sound may be included under either of two phonemes with equal justification, it has been the usual practice to choose the solution which is phonetically the more realistic. A large majority of linguists who have applied this criterion have preferred the interpretation /sp,st,sk/. It is the object of this paper to examine whether this preference is phonetically justified.

2. A perceptory experiment. **)

In order to investigate whether the stops after /s/ are auditorily closer to /p,t,k/ or /b,d,g/ a perceptory experiment was carried out.

2.1. The first part of this experiment consisted in letting native speakers of English identify a number of words which begin with sp, st, sc but whose initial [s] had been removed.

*) This paper is an abbreviated version of an article in the special Danish issue of "English Studies" (to appear in 1969). I am indebted to professor E. Fischer-Jørgensen for her kind assistance and many valuable suggestions.

**) For American English the results of this experiment are supported by two previous investigations: Lotz, Abramson, Gerstman, Ingemann, Nemser (4) and Reeds & Wang (5).

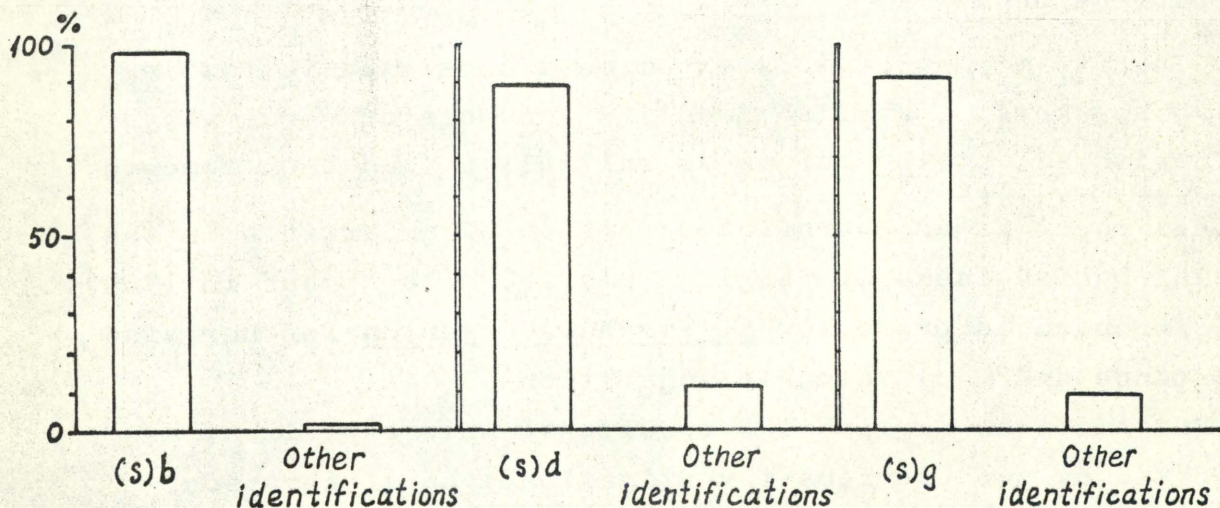
The following words were selected:

I	II	III
spear	pier	beer
spat	pat	bat
steam	team	deem
sty	tie	dye
scold	cold	gold
score	core	gore

The words were inserted into sentences and recorded by four persons (two English and two American) at a tape speed of fifteen inches per second. The test words from column I were then cut out of their environments. In the six words thus isolated the initial [s] was removed. By hand, the tape was moved slowly past the play-back head and was subsequently cut immediately after the friction of [s] had ceased, i.e. during the first part of the following stop.

The perceptory experiment consisted in letting 32 test persons (24 English and 8 American) identify 52 recordings of these six truncated words. Each of the words, which had been randomized, was played twice to the test persons, who were then asked to write down the English word they thought they heard.

The experiment showed that in 92% of the cases the test persons heard words beginning with /b,d,g/, i.e. the words which appear in column III, while in 8% of the cases they heard words beginning with another sound, which was nearly always /p,t,k/, i.e. the words in column II. It turned out that the words with sp were identified more consistently than the words with st and sc. This is shown in the following bar chart:



In order to examine British and American English separately the material was subsequently divided into two parts. The 24 Englishmen's judgment of the British English recordings showed 92% /b,d,g/ identification. The 8 Americans' judgment of the American English recordings displayed 98% /b,d,g/ perception.

2.2. In the second part of the perceptory experiment the test persons were asked to identify two recordings, one American and one British English, of the following sentence:

'Thanks, Stan, that'll be all.'

It was anticipated that this sentence in a number of cases would be confused with:

'Thanks, Dan, that'll be all.'

This was expected because the first part of the test had proved that the stop in st is perceived as a /d/. In this way the phonetic difference between the two sentences becomes very small and is probably restricted to a difference in the length of the [s].

The presumption that this distinction is precarious was supported clearly by this test. In only 58% of the cases the test persons identified the sentence correctly, whereas 'Dan' was heard in the remaining 42% of the cases.

3. Acoustic investigations. *)

Of all the recorded words in the three columns there were taken one duplex oscillogram, one pitch curve, and two intensity curves (logarithmically and linearly registered respectively). On these three curves and on the oscillogram the stops could be precisely delimited. In this way it was possible to measure the duration of the three stop series. Furthermore voicing and release burst could be examined.

*) B. Frøkjær-Jensen, of the Institute of Phonetics, has been of great assistance at the execution of the acoustic and articulatory parts of the investigation.

3.1. Duration of release stage.

The duration of explosion plus aspiration was measured in all the recorded words of the three types (216 words). It appeared that the average duration of this element of [(s)p, (s)t, (s)k] was 2 cs., while in the case of [p, t, k] it was 8 cs. As regards [b, d, g] the average duration of this element turned out to be 3 cs. On the basis of these measurements the only reasonable conclusion is to consider the stops after [s], as well as initial [b, d, g], unaspirated. [p, t, k], on the other hand, can only be termed aspirated.

3.2. Duration of hold stage.

On measuring this stage of the stops in the above mentioned 216 words it turned out that there was no significant difference between [p, t, k] and [b, d, g] in this respect. The average duration of the hold stage of [p, t, k] was 11 cs.; for [b, d, g] the mean length was 10 cs. In pairs the averages were the following: b/p: 10/12, d/t: 8/9, g/k: 12/11. The hold stage of [(s)p, (s)t, (s)k] was somewhat shorter (7 cs.). This, however, is to be expected in consonant clusters. On the basis of this material, consequently, no conclusions regarding force of articulation in English can be drawn from the duration of the hold stage.

3.3. Voicing.

An investigation of voicing showed very clearly that both [p, t, k] and [(s)p, (s)t, (s)k] were unvoiced. The traditional notion of [b, d, g] being articulated with a certain amount of voicing proved largely correct with regard to the two Americans. As far as the two Englishmen are concerned, however, divergent results were obtained. In the first place, all these sounds were unvoiced initially in a sentence. Secondly they were not fully voiced between vowels. It appears, then, that [b, d, g] in English may be realized in two different ways: with or without vibration of the vocal cords during the hold stage. It may be concluded that voicing cannot be regarded as any constant feature of these stops in English.

4. Articulatory investigation.

The last part of this investigation consisted in a physiological examination of intra-oral air-pressure. In the case of the two Americans and one of the two English test persons this was measured by inserting a thin plastic tube into the mouth behind the point of articulation. This tube was connected with an electric manometer,*) which registered the air-pressure in cm H₂O by means of a mingograph. At the same time a duplex oscillogram and two intensity curves were registered. The air-pressure of the fourth test person was measured by inserting the tube through the nose into the mesopharynx. In this way it was possible to measure also [k], [g], and [(s)k].

The experiment showed that two Americans (J.W. and M.W.) had a very clear difference between [p,t,(k)] and [b,d,(g)], which consisted in [b,d,(g)] having considerably lower pressure than [p,t,(k)]. Converting absolute into relative values by stating the percentage value of the voiced stops in relation to the unvoiced stops the following figures were arrived at:

	J.W.	M.W.
b/p	73	57
d/t	76	69

These results support the traditional view that [p,t,(k)] are fortes whereas [b,d,(g)] are lenes. This, however, was not the case with the English informants (N.S. and R.D.), who showed almost no difference of air-pressure between the two stop series:

	N.S.	R.D.
b/p	96	96
d/t	90	109
g/k	87	

 *) Constructed by A. Tybjærg Hansen and described in Eli Fischer-Jørgensen & A. Tybjærg Hansen (2).

The figures from the last table may seem surprising; but in an investigation by Eli Fischer-Jørgensen (1), voicing and intra-oral air-pressure have been demonstrated to be closely connected: voiced sounds have relatively low intra-oral air-pressure, unvoiced sounds relatively high pressure. Considering this negative correlation it could be anticipated that almost no difference of air-pressure could be demonstrated with the English test persons, for their [b,d,g]'s were predominantly unvoiced.

It was now to be expected that [(s)p,(s)t,(s)k], as regards intra-oral air-pressure, would be similar to [p,t,k], and that both these series would show relatively high pressure. The assumption proved correct for three out of four persons. The differences registered here were inconsiderable:

	N.S.	R.D.	J.W.
(s)p/p	98	98	99
(s)t/t	100	111	106
(s)k/k	96		

With regard to the fourth informant, who found it difficult to articulate with a plastic tube in her mouth, the pressure of [(s)p,(s)t] was somewhat lower than that of [p,t].

5. Summary and phonemic evaluation.

5.1. On the basis of this auditory, acoustic, and physiological investigation of stops after initial /s/ in English the following points may be underlined:

The perceptory experiment demonstrates that these sounds are significantly closer to /b,d,g/ than to /p,t,k/. This has been proved with American English in two previous investigations. The results obtained here, however, also suggest that British English is similar to American English in this respect.

The acoustic investigation shows that the stops after /s/ are unaspirated and unvoiced. They have the first of these features in common with /b,d,g/, the second with /p,t,k/. But the experiment also demonstrates that voicing is no constant feature of English /b,d,g/. There is, therefore, a hierarchic organization among the features of the stops in this position according to which aspiration is more important than voicing.

Lack of aspiration, consequently, forces speakers of English to evaluate the stops after /s/ as /b,d,g/.

It appears from the physiological investigation that [b,d,g] when voiced have lower intra-oral air-pressure than [p,t,k] and [(s)p,(s)t,(s)k]. When [b,d,g] are unvoiced, however, the three stop series have nearly the same intra-oral pressure.

5.2. With regard to the phonemic interpretation of these consonant groups this investigation demonstrates that the interpretation /sb,sd,sg/ is preferable if the criterion of "phonetic similarity" is applied. If, on the other hand, the criterion of "pattern congruity" is used, Hockett (3,p.159) is of the opinion that /sp,st,sk/ is the better solution, for as /p,t,k/ in codas are found together with /s/ (e.g. 'past'), while /b,d,g/ go with /z/ (e.g. 'razed'), we arrive at greater symmetry if this is also considered to be the case initially.

This argument, however, is not really convincing. In the first place, the structural possibilities of initial and final consonant clusters in English are clearly different, and it is therefore less obvious to generalize from final to initial position. Secondly, Hockett's interpretation of the final cluster of obstruents in 'passed' as /pa:st/ is not the only possible one: /pa:sd/ is also conceivable. It may be held *) that in a final cluster of two consonants in English the opposition between voiced and unvoiced consonant is suspended finally if voicing is distinctive with regard to the prefinal consonant. In a pair like 'raised' and 'raced' the two words are distinguished by means of vowel length and voicing of the sibilant. The final consonants, however, are respectively unvoiced ('raised') and unaspirated ('raced').**)

*) This solution has been pointed out to me by Jørgen Rischel, of the Institute of Phonetics, from whom I have received many valuable suggestions.

***) The possibility of final aspiration in 'raced', however, can hardly be excluded.

The form 'raced' may therefore be interpreted unambiguously as either /reist/ or /reisd/, and also be kept apart from 'raised' /reizd/ if the second solution is chosen. This implies that it is possible to operate with final /sb, sd, sg/, e.g. 'lisp' /lisb/, 'past' /pa:sd/, 'cask' /ka:sg/. If the initial consonant groups written sp, st, sc are also interpreted as /sb, sd, sg/ the demand for symmetry is satisfied. This solution does not in any way conflict with the principle of "phonetic realism" as progressive assimilations of voicing are to be expected in such environments. On these grounds /sb-, sd-, sg-/ seems to be a legitimate analysis.

References:

- (1) Eli Fischer-Jørgensen, "Beobachtungen über den Zusammenhang zwischen Stimmhaftigkeit und intraoralem Luftdruck", Zeitschr. f. Phonetik 16 (1963), pp. 19-36.
- (2) Eli Fischer-Jørgensen & A. Tybjærg Hansen, "An Electrical Manometer and its Use in Phonetic Research", Phonetica 4 (1959), pp. 43-53.
- (3) Ch. F. Hockett, A Manual of Phonology (1955).
- (4) Lotz, Abramson, Gerstman, Ingemann, Nemser, "The Perception of English Stops by Speakers of English, Spanish, Hungarian, and Thai", Language and Speech (1960), pp. 71-77.
- (5) J.A. Reeds & W.S.-Y. Wang, "The Perception of Stops after s", Phonetica 6 (1961), pp. 78-81.

(A more detailed list of references will be given in my forthcoming article.)