

VOICE ASSIMILATION OF STOP CONSONANTS AND FRICATIVES IN FRENCH
AND ITS RELATION TO SOUND DURATION AND INTRA-ORAL AIR-PRESSURE. *)

Oluf M. Thorsen

The phonemes examined are the consonants participating in the correlation voiceless:voiced or tense: lax:

(I) p t (k) f s ʃ**))

(II) b d (g) v z ʒ

The difference in voicing is the most characteristic auditory feature; but as this distinction is neutralized in groups consisting of I + II or II + I through regressive assimilation, the linguistically relevant difference is generally considered to be one of force of articulation. This can only be true if the force of articulation of the consonant is preserved in spite of the voice assimilation, which is the opinion held by most phoneticians of French. (1).

The investigations, here presented in a short, preliminary form, were made in 1956-57 in the Cardiologic Laboratories of the University Clinic, Copenhagen, and of Gentofte County Hospital, under the supervision of Eli Fischer-Jørgensen.

The French stops and fricatives were examined in respect to

1. voicing
2. intra-oral air-pressure
3. lip-pressure
4. duration
5. duration of the preceding vowel.

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**) /k/ and /g/ are excluded, because it was impossible to obtain curves of intra-oral air-pressure during these sounds from the unexperienced subjects.

Intra-oral air-pressure was picked up by a polyethylene tube (7 cm long, outside diameter 1.5 mm, bore 0.8 mm) inserted into the mouth behind the point of articulation and connected to an electrical condenser manometer (2). The outputs from the manometer and from a throat microphone were recorded on photographic paper (speed 10 cm per sec) by means of an Elema oscillograph. Simultaneously, these curves were visible on a cathode-ray oscilloscope. A small rubber bulb (19x12x8.5 mm) connected to the manometer was used for recording of lip-pressure. All examples were recorded on tape, and wide-band spectrograms were taken of many of the recordings in order to assure correct segmentation.

Subjects were five Parisians, one girl (MC) and four men (MN, GS, GV, JT), 20 to 31 years old.

The material consisted of 147 short phrases or sentences, like, for instance, "la robe de ma femme", "la robe te va mal", "l'Europe de nos jours", "l'Europe te rappelle", spoken 3 to 4 times by each subject: 20 examples with single consonants in different positions, 103 with the consonants in groups (I + I, II + I, I + II, II + II), and a list of 24 examples with /p/ and /b/ (for lip-pressure measurements).

1. Voicing.

Voicing was measured on the larynx curve (i.e. the oscillogram from the throat microphone) and on the air-pressure curve. The start of the consonant can be identified by a sudden rise of the air-pressure curve, plus a disturbance of the vibrations on the larynx curve.

In unvoiced postvocalic single consonants, the vibrations continue into the beginning of the consonantal phase. The mean value for 154 single consonants, initial or final in the stressed syllable, was 2.7 cs.

A voiced intervocalic consonant is normally 100 per cent voiced, - among fricatives there were scattered examples of incomplete voicing. In final position before a pause all voiced stop consonants are normally 100 per cent voiced, whereas fricatives normally have an unvoiced ending phase - in several cases these are only 40 per cent voiced, sometimes even less.

1.1. Unvoiced groups.

There were a few examples of insertion of [ə] in groups

of II + I, all resulting in non-assimilation of the voiced consonant.

The voiced beginning of unvoiced groups (I + I and II + I) was compared to the duration of the preceding vowel (phonemically short and long vowels were treated separately; the figures given refer to short vowels). It came out that in groups I + I the voiced beginning, measured in percent of the duration of the first consonant, decreased with increasing duration of the vowel, and the same was true of II + I up to a certain point: when the vowel exceeded a duration of about 4 cs, the effect was the opposite, so that now I (+I) and II (+I) became more and more different. In every example these findings were compared to the duration of the consonants, the length of the sentence, the distance from the final stressed syllable, and the syntactical structure. The following interpretations, which have to be tested on a larger material, are proposed:

The increase of the percentage of voicing in both I (+I) and assimilated II (+I) as the vowels (and the consonants) get shorter, due to longer test sentences and less stressed syllables, I explain as an increase of the assimilatory power of the preceding vowel at greater syllabic speed (3).

The increase of vowel duration beyond 4 cs seems to depend on the syntactical structure of the sentence, and the diverging behaviour with respect to voicing of I (+I) and II (+I) in these cases is therefore interpreted as an influence of secondary accent: an increase of stress on the preceding vowel (or a reduction of stress on the following vowel) puts the first consonant of the group in a stronger position and makes consonants of type II more able to resist the assimilatory influence of the second consonant.

1.2. Voiced groups.

Insertion of an [ə] did not occur in groups of stop plus stop or of fricative plus stop, but in groups of stop plus fricative it appeared in 35 out of 199 examples. Usually, the result of preserving the [ə] was that the consonants retained their original glottal articulation, but in /pəz/, /pəʒ/, and /pəv/, all variations of glottal articulation were found: no assimilation (1 ex.), regressive assimilation in spite of [ə] (11 ex.), reciprocal assimilation across the [ə] (3 ex.), and 4 cases of intermediate types.

Voiced groups without [ə]. The surprising result in this section was the high percentage of examples showing disturbance of the

vibrations or partial or complete absence of voice in groups of II + II. The following list shows the frequency of occurrence of instances in which the consonant group was incompletely voiced:

	II + II	I + II
stop plus stop	7%	11%
stop plus fricative	31% (!)	25%
fricative plus stop	45% (!)	42%

(Examples of fricative plus fricative were too scanty to give reliable percentages.)

It is true of these groups that if the first consonant is partially unvoiced, and the second voiced, it is always the end of the first consonant which is unvoiced, never its beginning, as claimed by Grammont (4). This seems to indicate that regressive voicing assimilation, rather than being an anticipation of vibrations, is a continuation of the vibrations of the preceding vowel, brought about by the laxness of the following consonant (5). But any effort to give detailed explanations of the assimilatory mechanism in groups of I + II is hampered by the irregularities in the II + II groups.

2. Intra-oral air-pressure.

2.1. Consonants in positions where they are not susceptible to voice assimilation.

a. Single Consonants. Intra-oral air-pressure is primarily determined by the degree of voicing: when the type II consonants are fully voiced, none of the subjects shows any overlapping between corresponding type I and type II consonants. All cases of overlapping are due to partial devoicing or weak amplitude of vibrations in the voiced sounds. /p/, /t/, /a/ have the highest pressure, next come /f/ and /ʃ/, then /z/, followed by the other voiced consonants /b/, /d/, /v/, /ʒ/. In stops and labial fricatives, the pressure of the type II consonant is normally 50 to 70% of its type I counterpart, in s/z and ʃ/ʒ the percentage is higher.

b. Second consonant in groups. Same results as above for 2.1.a.

c. First consonant in groups of I + I and II + II (i.e. no assimilation).

In this section there was some overlapping that could not be explained by deficient voicing. It turned out that the

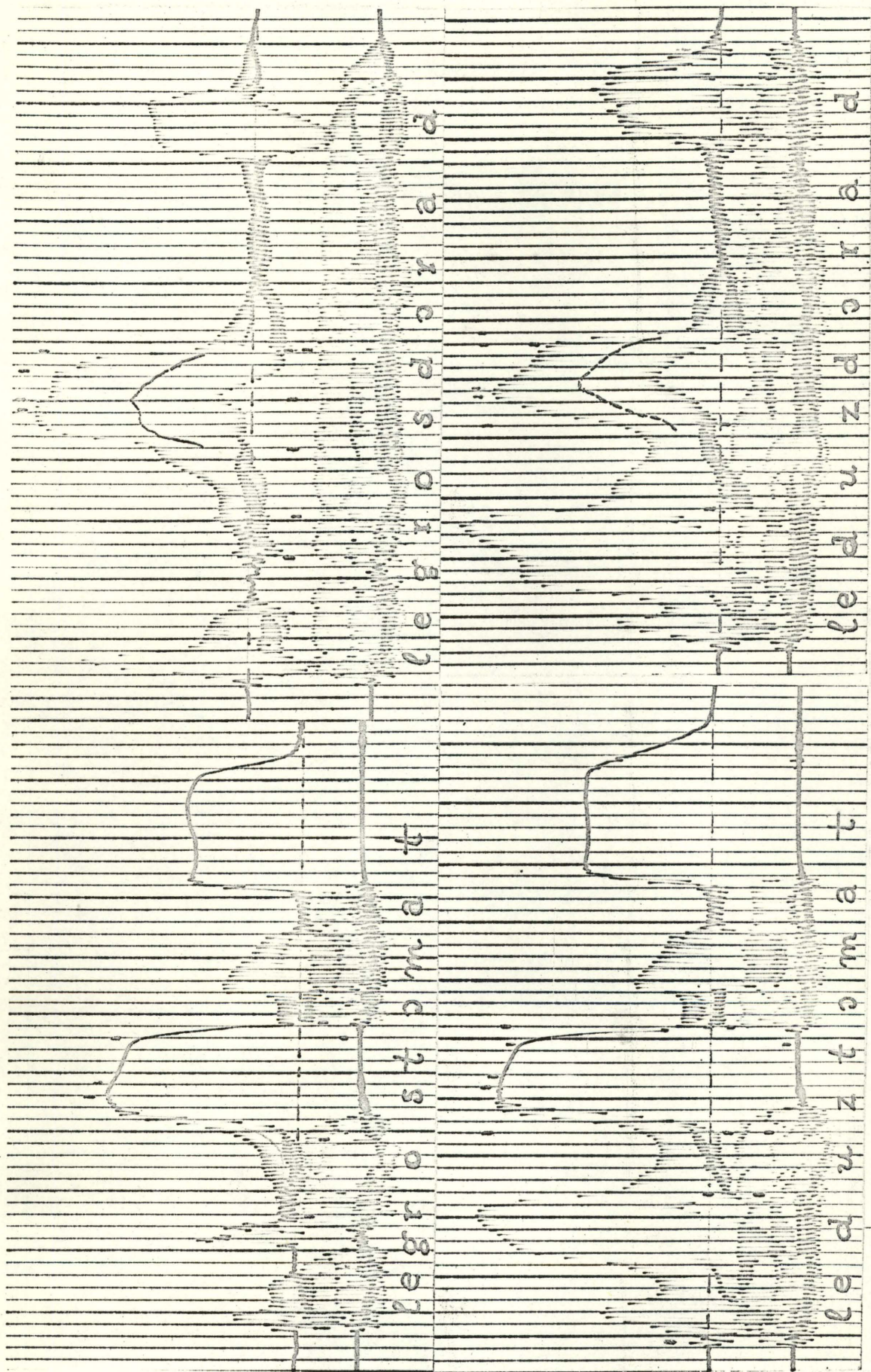


Fig. 1. Lower curve: oscillogram from larynx microphone. Upper curve: intra-oral air-pressure (a line has been drawn to indicate the short time mean value in voiced sounds). As stated in the text, the air-pressure is a little higher after /u/ than after /o/. The segmentation indicated is confirmed by or based on spectrograms.

relatively high pressure of the voiced consonant always occurred when the preceding vowel was less open than that found before the corresponding unvoiced consonant (the test sentences did not constitute minimal pairs). A re-examination of the entire material showed that the air-pressure is indeed higher the closer the preceding vowel is. As a close vowel has a higher air-pressure than an open vowel it seems that this difference is somehow carried on through the rest of the syllable.

2.2. Intra-oral air-pressure and voice assimilation.

Comparing all the four combinations of consonants, the findings mentioned above were confirmed: when preceded by vowels that did not differ in aperture, I(+I) and II(+I) had the same (high) air-pressure and II(+II) and I(+II) had the same (low) air-pressure. If the vowel before I + I was more open than the vowel before II + I, the air-pressure of II(+I) was higher than that of I(+I), and so forth.

The inevitable conclusion of this seems to be the following: when voice-assimilation in French is total, it is accompanied by a total assimilation of the intra-oral air-pressure.

3. Lip-pressure.

Lip-pressure is more difficult to explore than air-pressure. The rubber bulb hampers the articulation and must be kept very steady. Some of the subjects had great difficulties with this. As the difference in lip-pressure between /p/ and /b/ is smaller than the difference in air-pressure, there was a good deal of overlapping, and only two of the subjects (GV & JT) made a sufficient number of usable recordings. Furthermore, it turned out that the lip-pressure was smaller after rounded vowels than after unrounded vowels. This influence was not foreseen in the choice of examples for consonantal groups, so that comparison can only be made between unvoiced and voiced /p/, and between voiced and unvoiced /b/.

GV & JT showed a statistically significant difference between /p/ and /b/ in most positions, and in the consonantal groups the result was in most cases a lower pressure for voiced than for unvoiced /p/, and a higher pressure for unvoiced than for voiced /b/. I.e., it seems very probable that voice assimilation is accompanied by an assimilation of lip-pressure as well, but it is impossible to decide on the basis of the present data whether this assimilation is total or partial.

4. Consonant duration.

4.1. Single consonants.

Voiced and unvoiced consonants occurring in the same position show a great difference of duration with practically no overlapping: unvoiced consonants are longer than their voiced counterparts, the difference being greater in fricatives than in stops! For stops in non-final position, the difference in the length of the closed phase was not always quite clear, but the total length was unambiguous.

4.2. Consonant groups.

In the examples with consonant groups, several sources of variation disturbed the comparisons to such a degree that an unvoiced group was sometimes shorter than the corresponding voiced group. So I had to examine the influence of the following factors:

- a. rate of speech.
 - b. emphasis.
 - c. the distance from the final stressed syllable.
 - d. sentence rhythm.
 - e. the number of syllables and sounds in the example.
- a. The subjects were asked to keep a constant rate of speech.
 - b. A consonant is prolonged under the effect of emphasis, but emphasis did not occur among the examples with consonantal groups.
 - c. A consonant group preceding the final stressed vowel was longer than the same group placed before the penultimate vowel. When occurring before the antepenultimate vowel the group was always shorter than before the stressed vowel, but sometimes longer than before the penultimate.
 - d. The existence of secondary stress in French, which was doubted by Marguerite Durand (6), became evident from a comparison of the duration of the consonant groups in different syntactical positions. *Ceteris paribus*, a group consisting of the last consonant of a noun plus the first consonant of a postposited adjective was longer than the same group occurring medially in a word, and also longer than the same group found between the elements of compound words and between adjective plus noun. But if the postposited adjective was monosyllabic, a certain loss of stress sometimes appeared. These findings, and others, were corroborated by measurements of the vowels, and of each consonant in the groups in so far as delimitation was possible.

- e. In rather short utterances like the ones used in this investigation, the subjects will have a tendency to shorten the sounds in inverse ratio to the number of syllables. But also the number of sounds in the syllable has an influence on the sound duration: in particular, the consonant group was longer before a short stressed open syllable than before a long stressed vowel plus consonant or before a stressed vowel plus two consonants.

4.3. Consonant duration and voice assimilation.

Taking into account the above-mentioned factors, first comparing examples under equal conditions, and then weighing the different conditions against each other, I obtained the following results for the duration of the consonantal groups (all groups, all five subjects):

- I + I longer than II + I
 II + I longer than I + II
 I + II longer than II + II (?)

The differences between unvoiced and voiced groups were greater than the differences between assimilation and non-assimilation, especially in voiced groups.

That the second consonant is not exclusively responsible for the differences, will appear from the data about the first consonant in the group. Exact delimitation was possible only in part of the material (MN: in no cases -, GS & MC: only for p/b + s/z, GV & JT: practically everywhere). The duration of the first consonant in the group under maximally similar conditions of rhythm gave the following results:

- a. I(+I) longer than II(+II) (and (I+)I longer than (II+)II), i.e. the difference between I and II in non-assimilation groups is clear.
- b. II(+I) longer than II(+II) in about 75 per cent of the cases where the durations could be measured and compared directly, i.e., II is longer when devoiced. The second consonant makes the difference between II+I and II+II even greater.
- c. I(+I) versus I(+II): the very few directly comparable cases show no clear difference and might indicate that voiced I is not assimilated as to duration. The second consonant brings about a difference in the duration of the entire group: I+I is longer than I+II.
- d. I(+I) longer than II(+I) in all comparable cases, i.e., the assimilation of II is only partial.

- e. I(+II) longer than II(+II) in practically all comparable cases, i.e., if there is any assimilation of I, it is not total.
- f. II(+I) longer than I(+II) in about 60 to 65 per cent of the directly comparable cases, i.e., there is a slight tendency for unvoiced II to be longer than voiced I. This suggests that a greater number of examples under item c might have given a more pronounced shortening of voiced I.

5. Duration of preceding vowel.

Before a single consonant.

In absolutely final position the vowel was longer before voiced than before unvoiced consonant, with no overlapping at all, except for p/b, t/d, f/v in the recording of GS, and t/d, f/v in the recording of MC, and longer before voiced fricative than before voiced stop.

Before a consonant group.

The examples with consonant groups were chosen primarily for the investigation of intra-oral air-pressure, and usually the same vowel was repeated before the same consonant, whether assimilated or not, but a different vowel was found before its partner in the correlation. Moreover, as in the case of consonant duration, secondary stress influenced the vowel duration. Thus the directly comparable cases were not as many as might be desired. Nevertheless, they clearly showed that sonorisation prolongs, and desonorisation shortens, the preceding vowel by about 1 to 2 cs. Owing to the above-mentioned deficiency in the material, the difference of vowel duration before I+I and II+II is difficult to determine: it seems to be about 2 to 3 cs - and nothing can be said as to whether the assimilation is total or partial.

6. Conclusion.

The most important result of the present study has been to demonstrate that regressive voice assimilation in French stops and fricatives is accompanied by an assimilation of

- (1) intra-oral air-pressure
- (2) lip-pressure
- (3) the duration of the assimilated consonant
- (4) the duration of the preceding vowel.

This implies that the traditional theory, according to which the assimilation is limited to voicing, is incorrect.

There is still the possibility left that the so-called

"force of articulation" which is said to be preserved in spite of the voice assimilation, has nothing to do with intra-oral air-pressure, nor with lip-pressure in the way it has been examined here. It is conceivable that the slight shortening (lengthening) of the vowel together with the slight lengthening (shortening) of the assimilated consonant is in some contexts a sufficient perceptual cue. Another possibility to be considered is that the alleged difference in articulatory force may come out if other methods and instruments be used. Maybe, though, that the difference in force of articulation claimed by so many phoneticians of French, is something that is felt by the speaker, but not communicable to the listener - and maybe the all-important factor in the question of assimilation in French is the context, whether linguistic or extralinguistic. No Frenchman would misinterpret [lɔʁɔbdənozu:r] or [larɔptevamal]; but maybe he would misunderstand the intended meaning of [ʒəvjɛtparle] ([t] = 'te' or 'de') if he misunderstands the situation.

There is a lot of investigation to be done, especially in the field of perception tests.

References:

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