

A PHONETIC INVESTIGATION OF THE STØD IN STANDARD DANISH  
Eli Fischer-Jørgensen  
Copenhagen

The Danish stød is a prosodic phenomenon, whose distribution corresponds, roughly, to accent 1 in Swedish and Norwegian. However, in contradistinction to the tonal accents, the stød requires a long vowel or a short vowel plus a voiced consonant for its manifestation.

The present investigation started as a teamwork at the Institute of Phonetics in Copenhagen, but I have later enlarged the material considerably. It comprises 13 subjects in all, but all did not participate in the whole investigation. The acoustic analysis is based on around 1400 word pairs, the physiological investigations on somewhat smaller numbers. The words were read in frame sentences. The results have been published in ARIPUC 21, 1987, p. 55-265, and, in an abbreviated form, they will be published in two articles in *Phonetica*.

In older descriptions, including Jespersen, the stød was described as a glottal closure, i.e. acoustically as a pause. This has, however, not been confirmed by instrumental investigations, and in the present material a closure was found in only one, strongly emphatic, example. Irregular vibrations were, however, found in 70% of the corpus ( see Fig. 1), but the degree of irregularity is very variable.

The most consistent characteristic of the stød is a decrease in intensity, beginning about 6 cs after vowel start and comprising 12 dB, on the average ( see Fig. 2b) This decrease was found for all 13 subjects. A restricted spectrographic analysis showed that particularly the lower part of the spectrum is weakened.

Moreover, in words with stød all subjects have a higher fundamental in the first part of the syllable than in words without stød, the difference being about 21 Hz. In the second half of the syllable ( about 10 cs after vowel start) the fundamental often starts falling, sometimes rather abruptly ( see Fig. 2a). This fall was found in 55% of the examples, but in most of the other cases the measurement of  $F_0$  was made impossible by irregularities. This means that

a weak stød is characterised by a frequency drop, a strong stød by irregular vibrations covering the frequency drop. Even or rising  $F_0$  in the stød syllable is very rare. Because of the high start the second syllable of disyllabic words may be lower than the first syllable in contradistinction to the normal rising contour in the Copenhagen Standard. This happens particularly for speakers with a Jutlandish background ( see Fig. 2a).

Inverse filtering of a few words read by two subjects showed decrease of negative spikes, and the integrated curve showed lower flow in the second half of syllables with stød.

It is of interest to look for the physiological production mechanism behind these acoustic facts.

In his thesis (1944) Svend Smith advances the theory that the decisive factor is a strong ballistic contraction and relaxation of the expiratory muscles (demonstrated by means of surface electrodes). This will produce a corresponding rise and fall of the subglottal pressure. The pressure rise may cause a proprioceptive reflex activity in the vocal folds, and if their tension is not adjusted to the quickly falling pressure, irregularities may arise. The falling pressure also causes a fall in intensity.

Measurements of airflow ( 6 subjects) showed consistently lower airflow in the second part of the syllable.

It was not possible to record the expiratory muscles, but subglottal pressure was recorded for one subject. It was normally higher in the beginning of a word with stød than in words without stød ( see Fig. 2e), but the difference was only 1-2 cm  $H_2O$ , and the fall was very slow. This cannot explain the fall in intensity nor the frequency contour.

The constriction of the glottis was examined by means of fiberoptics for 6 subjects (50 frames per second). Vowels with stød show constriction of the glottis in the latter part of the syllable, and there is often a contraction of the false vocal folds, but with large intersubjective variation ( see Fig. 3 ).

Electromyography of the muscles of the larynx did not show any particular activity of posticus or transversus; but 5 out of 7 subjects had strong activity in the vocalis

muscle in words with stød with a peak at the start of the frequency drop (see Fig. 2d). There was also often a (slightly earlier) peak in cricothyreodeus, which explains the high start of the syllable with stød. But there was generally no valley corresponding to the fall in frequency (except sometimes for one subject Fig. 2e). Lateralis (3 subjects) had a peak for the stød like vocalis.

The extra rise in subglottal pressure often precedes the extra vocalis activity, and in these cases the latter might be a reflex innervation, but the rise in subglottal pressure may also start later, and there is much overlapping between the subglottal pressures in words with and without stød, whereas there is hardly ever overlapping in the vocalis recordings, which means that there are many cases of strong vocalis activity without any higher subglottal pressure.

Probably the stød involves an independent contraction of several muscles (expiratory muscles, vocalis, lateralis, cricothyreodeus, and possibly more). The stød seems to be a type of dynamic accent; and the irregularities are hardly due to maladjustment, as Smith assumes, but rather part of an intended special phonation type.

However, two subjects did not show any particular vocalis activity in words with stød. In one of the cases the electrodes may not have been in the right position. But in the other case this is not probable, since this subject was recorded twice with the same result. This subject also had very strong contraction of the false vocal folds, and he often had rising fundamental in the second half of the syllable instead of the normal fall.

It is possible that he uses other muscles for the stød, e.g. lateralis and the constrictor muscles. It was, unfortunately, not possible to try these muscles (It is well known that EMG of the larynx muscles is not very pleasant for the subjects, and only few want to repeat the experience).

The present investigation should be supplemented by a perceptual analysis of the relative importance of the different acoustic cues.

Fig. 1

Stød with irregular vibrations

Fig. 2

Average curves  
of 10 recordings  
(see the text)  
Subject BF

Fig. 3

Fiberoptics of the  
vocal folds in the  
first (A) and the  
second (B) part of  
the vowel with stød  
1 subject HU  
2 subject JR