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# DISTRIBUTION OF PHONATION AND PAUSE DURATIONS IN FLUENT SPEECH AND STUTTERERS SPEECH

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This work is a fragment of investigations into an objective method of evaluation of speech fluency. The paper presents statistical distributions of phonation and pause durations in utterances of stutterers speaking with a simultaneous auditory feedback and synchronously with an echo and in utterances of fluently speaking subjects. It is shown that the speech envelope can be a source of information about both speech velocity and the degree of speech non-fluency. The most probable phonation and pause durations have been found to exist and a correlation between these durations and the duration of one syllable has been revealed. This make makes a speech velocity evaluation possible on the basis of statistical distributions of phonation and pause durations. Distributions of phonation and pause durations in fluent and non-fluent speech have been compared. Non-fluent speech contains shorter phonations than fluent speech. Total phonation durations have been determined in utterances of stutterers and fluently speaking subjects. They are much shorter in non-fluent utterances than in fluent ones. The total phonation distribution can be an important parameter in an evaluation of speech fluency.

## 1. Introduction

The main parameters in an evaluation of results of a therapeutic influence on the speech process in stutterers are: speech velocity and stuttering intensity [2, 3, 5 – 8]. At present, they are measured by auditory methods. The speech velocity is determined by measuring fluently pronounced syllables and the time period they take. In the case of stutterers these fluent sections are short and the measurements are subject to a significant error. The stuttering intensity is determined by a number of errors characteristic of stuttering, such as: repetitions, insertions, blockades etc. per 100 fluently pronounced syllables.

The aim of the research reported in this paper is to develop an objective method of evaluating non-fluency of speaking in stutterers.

It is strictly connected with the answer to the question, what exactly is stuttering. According to some authors [4, 9], stuttering is a disturbance at the beginning of speech sounds, resulting in a wrong duration and accent of the motoric units they precede. The greater vocal effort at the beginning and pronunciation of speech sounds leads to disturbances in time relations between periods of activity (phonations) and periods of rest (pauses) of articulators.

Distributions of phonation and pause durations in fluent and non-fluent speech are the subject of this work.

## 2. Apparatus and measurement procedure

Speech signals from a tape-recorder (*1*) were put through an analogue detector of envelopes (*2*), converted to digital signals (*A*/*D* converter – (*3*) and memorized (*4*) on

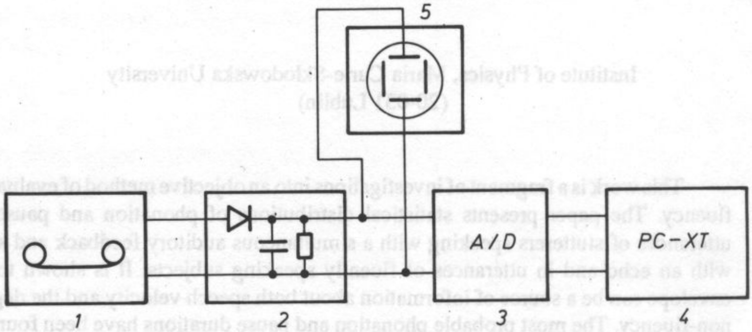


FIG. 1. Block diagram of the set-up for measuring phonation and pause durations.

floppy disks (Fig. 1). The maximum levels of analogue signals fed to the converter were monitored at a CRT (*5*). An exemplary shape of a speech envelope is presented in Fig. 2. The dynamic range of analogue signals was 40 dB. The conversion time of the analog-to-digital converter was 5 ms. 100 second records were made for 30 stutterers speaking: a) with a simultaneous auditory feedback, b) synchronously with an echo [1], and for 30 fluently speaking subjects.

The computer procedure were developed:

1) measurement of phonation and pause durations resulting in a statistical distribution of these parameters at an arbitrary width of the time interval,

2) measurement of the total phonation time during an utterance.

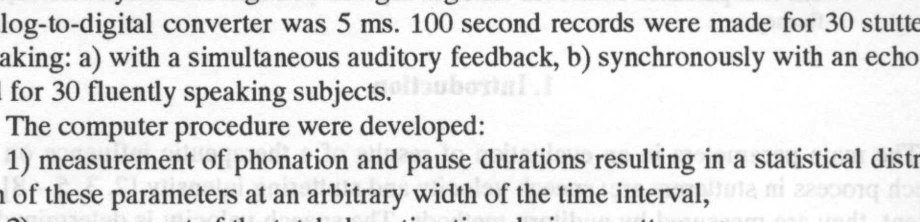


FIG. 2. Exemplary shape of a speech envelope.

## 3. Description of persons to speech analysis

### 3.1. Stutterers

The group of stutterers subjected to speech analysis comprised 23 men and 7 women. Their age ranged from 11 to 21 years. The stuttering intensity defined as a number of errors per 100 syllables ranged from 1 to 38 (the average value was 16 errors per 100 syllables). The speech velocity when speaking with a simultaneous auditory feedback was from 2.3 to 5.1 syllables per second (average: 4.0 syl/s), while with echo it was from 0.7 to 2.5 syl/s (average: 1.8 syl/s). The stuttering intensity when speaking with an echo decreased to a lower value ranging from 0 to 7.4 errors per 100 syllables in individual stutterers (average: 1.7 errors per 100 syllables). The subjects described simple pictures.

### 3.2. Fluently speaking persons

The group of fluent speakers included 15 students who described the same pictures as the stutterers did. The examinations included 100 second fragments of official speeches of 15 members of Parliament recorded from the radio.

Note that the subjects were intentionally not selected for their age or for their sex. This rule applied both to fluently speaking subjects and to stutterers. This follows from the fact that it is the aim of the research to reveal features which differentiate the speech of stutterers from that of fluently speaking subjects, no matter what their age or sex.

## 4. Relationship between statistical distributions of phonation and pause durations and speech velocity

Examples of statistical distributions of phonation and pause durations (in the range of 1 s) in utterances of stutterers speaking (a) with simultaneous auditory feedback (unaided speaking) and synchronously with an echo are shown in Fig. 3.

Pronounced maxima in numbers of phonations and pauses distributions can be observed. Their locations change with speech velocity (which was 3.5 syl/s in the case of utterances shown in Fig. 3 a and 2.4 syl/s in Fig. 3 b). Figure 4 shows a dependence of the most frequent values of phonation durations $t_{ph}$ and the most frequent values of pause durations $t_p$ and their sum $t_{ph} + t_p$ on an average time of pronunciation of one syllable (the reciprocal of speech velocity – $t_s$). The most frequent values of phonation durations increase with the duration of one syllable duration. This relationship is approximately described by

$$t_{ph} = 0.86\, t_s - 0.04\, [s]. \quad (1)$$

Pause durations increase only slightly with the duration of one syllable

$$t_p = 0.18\, t_s + 0.02\,[s]. \tag{2}$$

The best correlation can be observed between the sum $t_{ph} + t_p$ and the average duration of one syllable

$$t_{ph} + t_p = 1.04\, t_s - 0.02\,[s]. \tag{3}$$

This leads to the next conclusion that the reciprocal of the sum $t_{ph} + t_p$ is correlated with the speech velocity (Fig. 5)

$$V_{ph+p} = 0.99\, V_s + 0.06$$

$$\left( V_{ph+p} = \frac{1}{t_{ph} + t_p},\ V_s = \frac{1}{t_s} \right). \tag{4}$$

## 5. Differences in statistical distributions of phonation and pause durations observed in fluent and non-fluent speech

The distributions of phonation and pause durations in stutterers speaking with a simultaneous auditory feedback (non-fluent speech) are different from the distributions obtained when speaking with an echo (almost fluent speech). In order to visualize these

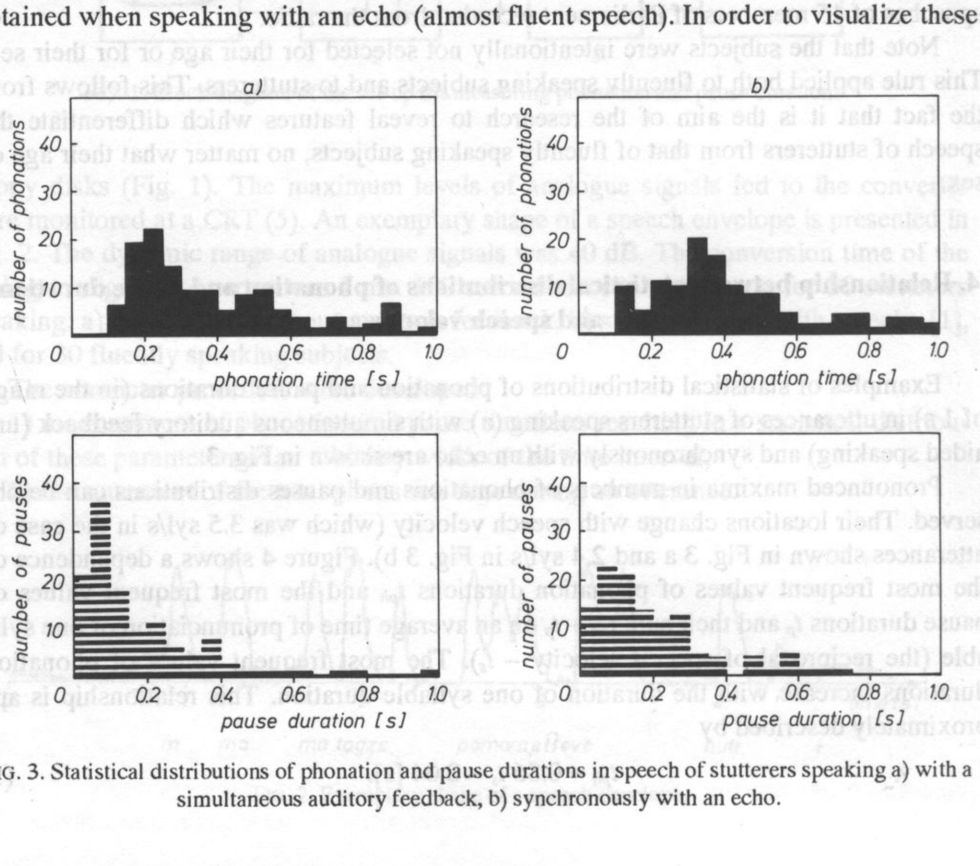


FIG. 3. Statistical distributions of phonation and pause durations in speech of stutterers speaking a) with a simultaneous auditory feedback, b) synchronously with an echo.

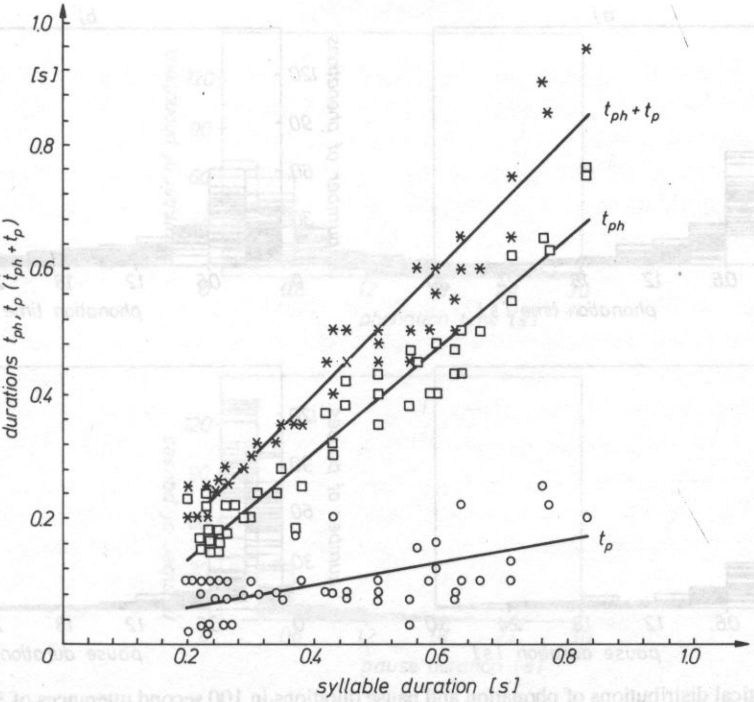


FIG. 4. Dependence of phonation durations corresponding to maxima ($t_{ph}$), pause durations corresponding to maxima ($t_p$) and their sum $t_{ph} + t_p$ on an average time of pronunciation of one syllable (the reciprocal of speech velocity).

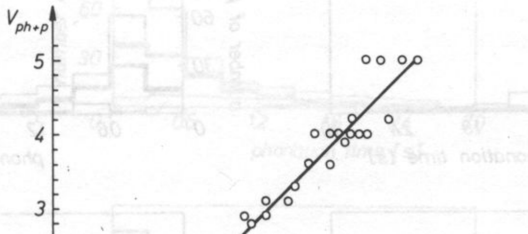


FIG. 5. Correlation between $V = \dfrac{1}{t_{ph} + t_p}$ and $V_s$ determined by a number of syllables pronounced during one second.

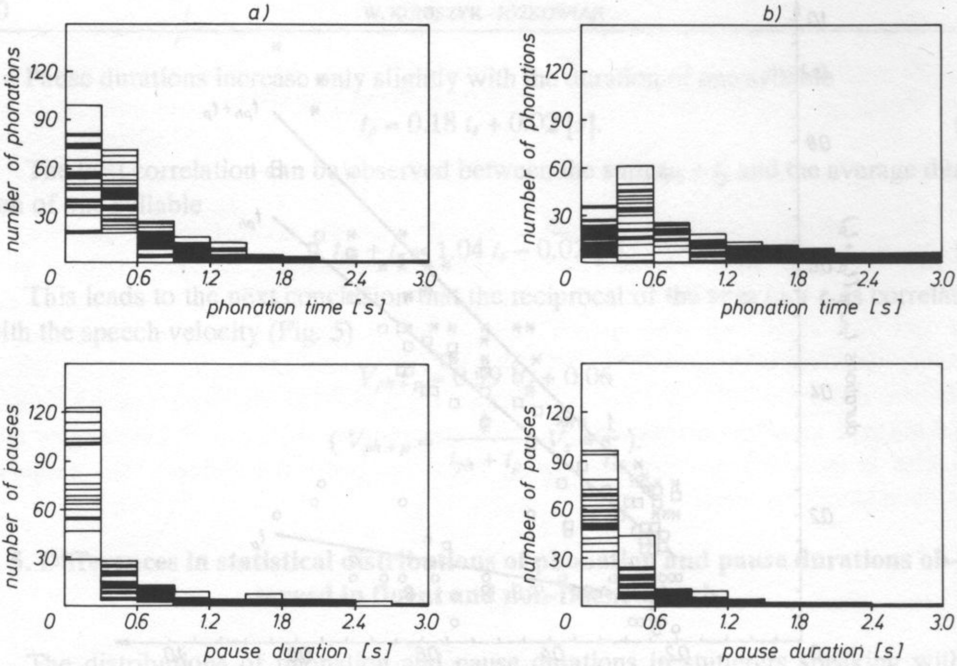


FIG. 6. Statistical distributions of phonation and pause durations in 100 second utterances of 30 stutterers speaking a) with a simultaneous auditory feedback, b) with an echo.

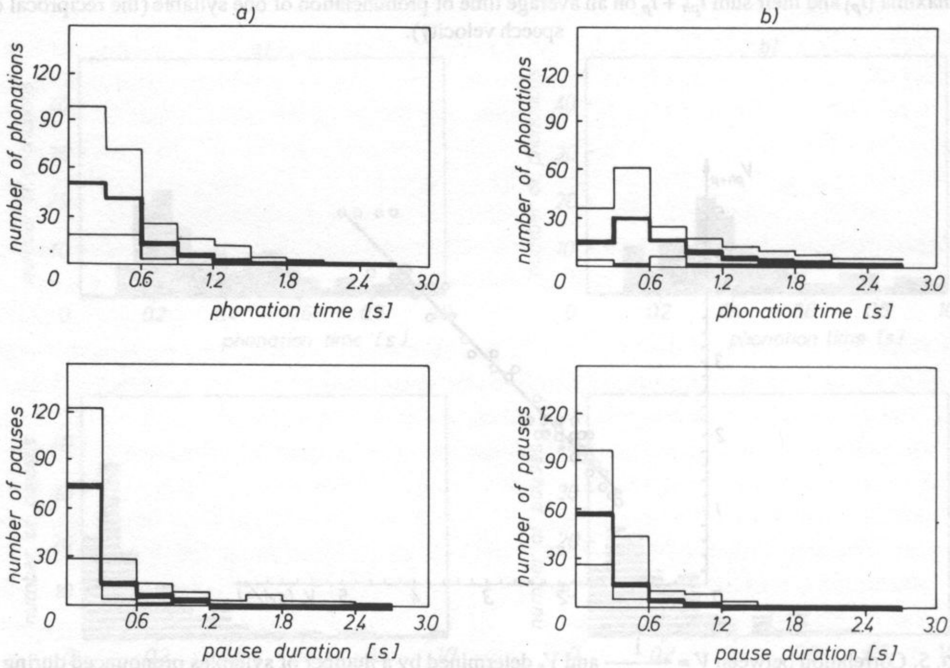


FIG. 7. Average (heavy line), maximum and minimum occurrences of phonation and pause durations in relevant time intervals calculated from utterances of 30 stutterers speaking a) with a simultaneous auditory feedback, b) with an echo.

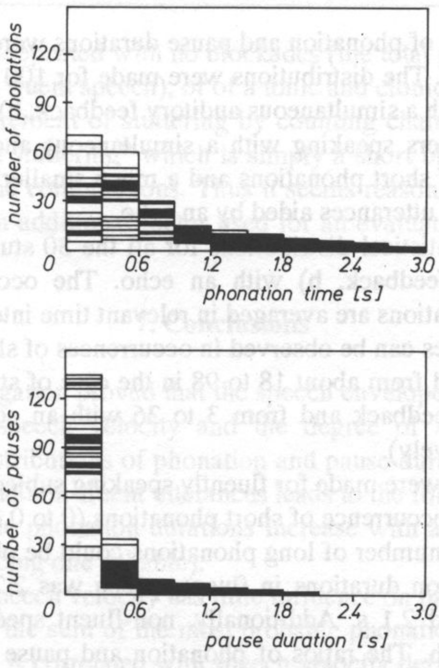


FIG. 8. Statistical distributions of phonation and pause durations in 100 second utterances of 30 fluently speaking subjects.

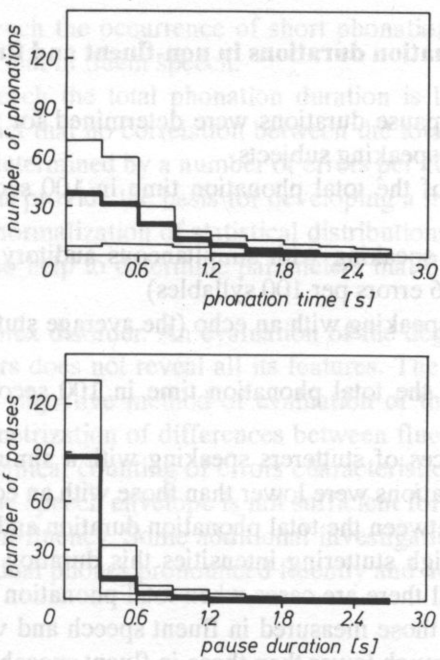


FIG. 9. Average, maximum and minimum occurrences of phonation and pause durations in relevant time intervals calculated from utterances of 30 fluently speaking subjects.

differences, distributions of phonation and pause durations were prepared assuming the time interval width 0.3 s. The distributions were made for 100 second utterances of 30 stutterers speaking a) with a simultaneous auditory feedback, b) with an echo.

Utterances of stutterers speaking with a simultaneous auditory feedback show a much greated number of short phonations and a much smaller number of long phonations in comparison with utterances aided by an echo.

Figure 6 presents statistical distributions for all the 30 stutterers speaking a) with simultaneous auditory feedback, b) with an echo. The occurrences of indivudual phonation and pause durations are averaged in relevant time intervals (Fig. 7).

Significant differences can be observed in occurrences of short phonation durations (0 to 0.3 s) which ranged from about 18 to 98 in the case of stutterers speaking with a simultaneous auditory feedback and from 3 to 36 with an echo (the average values were 49 and 15, respectively).

Similar distributions were made for fluently speaking subjects (Figs. 8 and 9).

In fluent speech the occurrence of short phonations (0 to 0.3 s) ranged from 4 to 70 (average: 37). A greater number of long phonations could be observed here. The range of uninterrupted phonation durations in fluent speech was 2.7 s, while in non-fluent speech it did not exceed 2.1 s. Additionally, non-fluent speech contains more long pauses that fluent speech. The ratios of phonation and pause durations in fluent and non-fluent speech were determined by a measurement of total phonation durations.

## 6. Total phonation durations in non-fluent and fluent speech

Total phonation and pause durations were determined for utterances of all the 30 stutterers and 30 fluently speaking subjects.

The average values of the total phonation time in 100 second utterances of stutterers were:

a) 55 seconds when speaking with simultaneous auditory feedback (the average stuttering intensity was 16 errors per 100 syllables)

b) 72 seconds when speaking with an echo (the average stuttering intensity was 1.7 errors per 100 syllables).

An average value of the total phonation time in 100 second utterances of fluent speakers was 72 seconds.

In almost all utterances of stutterers speaking with a simultaneous auditory feedback, total phonation durations were lower than those with an echo. However, no correlation can be observed between the total phonation duration and the stuttering intensity. Though in the case of high stuttering intensities this duration is significantly smaller than in fluent speech, still there are cases when total phonation durations at high levels of stuttering are close to those measured in fluent speech and vice versa, at low levels of stuttering they can be much lower than those in fluent speech. This is connected with the various forms stuttering can assume. It can be of a tonic nature, i.e., with a predomination of blockades (then the total phonation time will be small); of a clonic nature, when speech sounds are repeated with no blockades (the total phonation time would be close to that observed in fluent speech); or of a tonic and clonic nature.

The auditory measurement of stuttering by counting characteristic errors does not reveal so-called "hidden stuttering" which is simply a short blockade or an intentional avoidance of some phone combinations. Thus it seems reasonable to measure the total phonation duration as an additional factor used for an evaluation of speech fluency or therapeutic results.

## 7. Conclusions

The reported investigation proved that the speech envelope could be a source of information about both speech velocity and the degree of speech non-fluency. An analysis of statistical distributions of phonation and pause durations and a total phonation duration in fluent and non-fluent utterances leads to the following conclusions:

1. The most probable phonation durations increase with a drop in speech velocity (longer time of pronouncing one syllable).

2. A slow-down in speech velocity has little influence on pause durations.

3. The reciprocal of the sum of the most probable phonation duration and the most probable pause duration is correlated with speech velocity defined as a number of syllables pronounces during 1 second. The relationship can be used for speech velocity measurements.

4. In non-fluent speech the occurrence of short phonations (shorter than 0.3 s) is significantly lower than that in fluent speech.

5. In non-fluent speech the total phonation duration is lower than that in fluent speech in spite of the fact that no correlation between the total phonation duration and the stuttering intensity determined by a number of errors per 100 syllables.

The presented results provide the basis for developing a method of speech velocity evaluation through the normalization of statistical distributions of phonation and pause durations. They will also help to determine parameters that differentiate fluent speech from that of stutterers.

Stuttering is a complex disorder. An evaluation of the degree of this disorder by a simple counting of errors does not reveal all its features. The aim of the presented research is to develop an objective method of evaluation of the degree of speech non-fluency through a parametrization of differences between fluent and non-fluent speech and not through a mechanical counting of errors characteristic of stuttering. The information obtained from the speech envelope is not sufficient for an explicit evaluation of the degree of speech non-fluency. Some additional investigation into the differences in characteristics of individual phones pronounced fluently and not fluently will follow.

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