On The Scientific Works Of Maria Steffen-Batóg[1]

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Abstract

This paper discusses the works of Professor Maria Steffen-Batóg. We begin with a short biographical note. The main part of the paper is divided into three parts, corresponding to the results obtained by Professor Steffen-Batóg in the domains of: 1. phonostatistics, 2. transcription algorithms, and 3. prosody of the Polish language. A reference like MSB n denotes the n-th position on the list of all academic publications of Professor Maria Steffen-Batóg included at the end of this paper.

Maria Steffen was born on October 30, 1933 in Poznań. She went to primary school in Lubawa and Wiele, after her family had moved north to Pomerania. In the years 1945–1951 she was a student of a high school (lycée) in Poznań.

In this paper I would like to concentrate on Maria Steffen-Batog's academic career only. The reader interested in the story of the Steffens family will find the information in Professor Wiktor Steffen's autobiography (*Moja droga przez życie* [*My Way Through Life*], Wydawnictwo Pojezierze, Olsztyn 1976; second enlarged edition — 1987).

In the years 1951–1955 Maria Steffen studied Polish Philology at Poznań University. She chose to specialize in linguistics, and in 1955 she defended her M.A. thesis entitled *Niektóre zjawiska dialektyczne w* Historii Aleksandra Macedońskiego o walkach *z 1510* [*Some dialectological phenomena in* The History of His

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Battles by Alexander (the Great) of Macedon *as it was published in 1510*]. The work was supervised by Professor Władysław Kuraszkiewicz.

On July 1, 1955, she began her professional career as a junior assistant in the Department of Phonography of Poznań University. The beginnings of this Department go back to 1946. It first functioned (in the years 1946–1951) as Phonetic Archives and was headed by Ludwik Zabrocki. In the years 1951–1953 when the Archives became a Department, its staff included among others Leon Kaczmarek, Ferdynand Antkowski and Zenon Sobierajski. The subject matter of the research work in which the Department was engaged covered experimental phonetics, embriology and pathology of speech, and also the collecting, storing and linguistic analysis of dialectological data. When in 1954 Wiktor Jassem became Director of the Department, the institution started specializing in phonetics only. It was then included first into the Department of the Polish Language, then into the Department of General Linguistics to become finally (in 1963) an independent Department of Phonetics. In the meantime, a second research institution was established in Poznań to study experimental phonetics. It was the Laboratory of Acoustic Phonetics at the Institute of Fundamental Problems of Technology organized and headed (until 1993) by Wiktor Jassem (as the Institute belonged to the Polish Academy of Sciences or PAN, the Laboratory was formally independent of the University).

Two years after she had graduated from the University Maria Steffen published her first paper entitled: *Częstość występowania głosek polskich* [MSB 1] [*The Occurrence frequency of Polish speech sounds*] in the *Bulletin of the Polish Linguistic Society*. This work is still one of the most important contributions to phono-statistical analysis of Polish. It was the first publication of its kind and as such it was quoted by dozens of scientists. It also found some important practical applications in, for instance, audiometry and in studies that dealt with qualitative aspects of telecommunication systems. It is worth remembering that the author had to make all her calculations (on a corpus of data including some 50 000 speech sounds), without the help of electronic calculating machines (not available at that time).

Two other early works by Maria Steffen are: MSB 2 (on the average spectra of Polish speech) and MSB 3 (where she discussed tests for the investigation of the distinctness and intelligibility of Polish speech). From MSB 3 onwards, the author has published all her works as Steffen-Batóg [or Steffen-Batogowa, in Polish].

Maria Steffen-Batóg was granted the degree of Doctor of Humanistic Studies on December 12, 1963 for a dissertation, entitled *Analiza struktury przebiegu melodii polskiego języka ogólnego* [*A Structural Analysis of the Speech Melody of*

Standard Polish]. An abridged version of the Ph.D. dissertation appeared in German as MSB 4. A more complete version of this dissertation was published only in 1996 as MSB 39. Her work was supervised by Professor Wiktor Jassem.

The dissertation was again the first attempt to structurally analyse the intonation system of Polish. On the basis of an extensive material (consisting of 10 000 stress groups) an inventory of functional intonation units (intonemes) was established. It was discovered that there are 26 distinct intonemes in Polish. The dissertation, however, was important not only on account of its empirical results. It must also be considered important for theoretical linguistics due to the conceptual constructs introduced into the work with complete methodological mastery. The terminological apparatus might serve as a starting point to working out a general theory of intonational systems which would also be formally well-grounded.

In the following years Maria Steffen-Batóg published other works which dealt with intonation systems (i.e. MSB 6, 7, 10, 11). In some of them a new issue appeared, which pertained to theoretical foundations and practical feasibility of voice identification techniques. In MSB 7, for instance, she discusses a possibility of describing personal voice characteristics on the basis of an analysis of the statistical distribution of averaged fundamental frequency values. The paper aims at "the definition of the temporal extent of an utterance necessary for a statistically reliable distribution in each voice and an evaluation of the different central tendency and dispersion measures for the discrimination of distributions characteristic of the individual voices" (MSB 17, p. 23) — writes the author in her comments on MSB 7. In the sixties Maria Steffen-Batóg published her first paper on Polish stress structures (MSB 5); a subject she returned to in many of her later works.

On November 1, 1964 Maria Steffen-Batóg was promoted to the position of senior assistant (adiunkt in Polish) in the Department of Phonetics. In 1969 the Department was included (as a Phonetic Section) into the Department of Applied Linguistics, which in turn became part of the Institute of Linguistics newly established on October 1, 1973 at Adam Mickiewicz University in Poznań (henceforth: UAM).

On the basis of her dissertation *Teoretyczne podstawy automatyzacji transkrypcji fonematycznej tekstów polskich* [*Theoretical Foundations for the Automatization of Phonemic Transcription of Polish Orthographic Texts*] Maria Steffen-Batóg was granted the degree of "Habilitated Docent of Humanistic Studies" (equivalent of assistant professor; in conformance with the tradition of Medieval Universities a scholar granted the *venia docendi* had the right to give lectures at a university). The degree defined her specialization (in linguistics) and it was granted on June 27, 1974 by the Council of the Philological Faculty at UAM. The degree was then approved by the Central Qualifying Committee attached to the Prime Minister's Office. The Committee's decision reached the University on November 25, 1974 and on March 1, 1975 Maria Steffen-Batóg was promoted to the position of docent (assistant professor).

The dissertation was published as *Automatyzacja transkrypcji fonematycznej tekstów polskich* [*Automatization of Phonemic Transcription of Polish Orthographic Texts*] (MSB 16). Some of the results, however, which were to be obtained therein had been announced in papers published earlier, i.e. in MSB 12, 13, and MSB 15. Once more, Maria Steffen-Batóg was the first Polish scholar to deal with the problems pertaining to the automatization of phonemic transcription. Here is what she has to say on her investigations in the first chapter of the monograph (MSB 16, p. 10):

> The investigations the results of which we shall present in the present monograph were begun in the spring of 1970 at the suggestion of M. Warmus. They aimed at solving the problem of automatization of phonemic transcription of orthographic texts in Polish. The goal naturally presupposed a re-analysis of the problem raised in the above quoted work of Doroszewski, that is the issue of the mutual relationship between speech and writing in Polish.
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> Yet, when I have analysed the problem in some more detail, it turned out that despite the quite common beliefs to the contrary, the orthography in Polish is characterized by considerable discrepancies between speech and writing which make the automatization venture particularly difficult. Another difficulty of a more specific nature lay in the fact that the problem of correct pronunciations of quite a number of words in Polish — particularly those of foreign origin and professional terms — has not been settled. Thus, the lack of a Polish pronunciation dictionary seriously complicated the investigations (such a dictionary would also be extremely useful for social and practical reasons).
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> A preliminary solution of the problem was arrived at relatively quickly, within only a couple of months. That was possible thanks to to the use of the elementary conceptual apparatus of the algebra of sets and algebra of words which helped me formulate - in a precise and extremely clear way - my rules of a transcription algorithm. Formal properties of the apparatus made it relatively easy to discover all the possible errors, contradictions and gaps at an early stage of the investigation. And that was of fundamental importance as the number of rules to formulate (some of which were extremely complex) was huge. I should add at this point that it is the use of the algebraic appara-

> tus that differs methodologically my approach from that of all other authors who deal with similar problems. Basic information on the conceptual apparatus and methods used in my monograph can be found in the following two short papers published earlier: M. Steffen-Batogowa (1973a) and (1973b) [MSB 12, and MSB 13 — J.P.].
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> The preliminary results which I mentioned earlier were verified in the spring of 1971 by means of a series of tests in which a calculating machine Odra 1204 was used. That was done by M. Warmus who transformed my algorithm into a computer program and made several test transcriptions. The details of the experiments were discussed by M. Warmus (1973); here I would only like to note that the results of the test were even better than we had expected.
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> Most cumbersome and time consuming — as in the case of all other authors who dealt with similar problems — turned out to be the problems concerning rare and exceptional phenomena, which usually disobey standard rules. To register and account for all such phenomena I had to analyse systematically — under an appropriate point of view — the available language material concerning the whole of the Polish language. That was a huge task and yet unavoidable, as only its completion allowed me to arrive at the definite solution of my problem the results of which are presented in detail in this monograph. The solution seems to surpass in its completeness all other competing solutions discussed in the literature of the subject with which I am familiar.

Maria Steffen-Batóg's pioneering work stimulated investigations in other scientific centres. An information science center in Warsaw (see: Bolc and Maksymienko 1981; Chomyszyn 1986), for instance, worked out computer programs which not only automatized the transcription process, but could also be used to perform statistical analyses. Besides, the algorithms worked out by Maria Steffen-Batóg were applied in the research work of the Department of Acoustic Phonetics at the Polish Academy of Science Institute of Fundamental Problems of Technology (Poznań Section). The reader can find more information on the recent results of the research related to Professor Steffen-Batóg's transcription algorithms in the following papers: Nowakowski (1995) (English translation included in this volume) and Nowak (1995).

Maria Steffen-Batóg's works published during the last two decades dealt mainly with two types of problems:

1. the formal foundations of constructing transcription algorithms and the formulations of such algorithms (MSB 12, 13, 15, 16 all mentioned earlier and also MSB 18, 30, 31, 32);

2. the perception and physical manifestation of stress and stress structures (MSB 19, 21, 23, 24, 25, 27, 28).

A separate group of her works includes those dealing with history of acoustic phonetics (MSB 8, 14, 17, 22) and a paper published together with Tadeusz Batóg (MSB 20) where the authors try to account for the notion of phonetic distance between speech sounds within a set of Polish speech sounds on the basis of appropriate classifications of those sounds.

Her most recent works (MSB 34, 36) discuss certain problems pertaining to interpersonal differences in expressing and perceiving emotions in speech.

Since 1975 Maria Steffen-Batóg has been Director of the Department of Phonetics. In the years 1975–1991 the Department formed part of the Institute of Linguistics at UAM, then (on January 1, 1992) it was included into the Department of General and Applied Linguistics, which in 1994 was transformed again into the Institute of Linguistics. In the years 1981–1984 and 1988–1990 Maria Steffen-Batóg was Vice-Director of the Institute of Linguistics (responsible for research work). In 1976, Maria Steffen-Batóg's scientific accomplishments were honoured with the Minister's award. In 1984, she received form the International Phonetic Association a *Certificate of Award* for her research in phonetics and also for her work as a member of the Association.

Since 1982 Maria Steffen-Batóg has been Vice-Chairman of the Board of Directors of the Polish Phonetic Association and Chairman of the Poznań Section of the Association.

Maria Steffen-Batóg's didactic interests include problems pertaining to phonetics, phonology and speech therapy (logopedy). She has supervised dozens of M.A. theses.

The five Ph.D. dissertations written under Professor Maria Steffen-Batóg's supervision are as follows:

Marian Ziombra's (Institute of Russian Philology UAM) dissertation entitled: *Nauczanie intonacji języka rosyjskiego na studiach rusycystycznych w świetle badań nad jej percepcją* [*Teaching Russian Intonation in Institutes of Russian Studies in View of Investigations on Its Perception*] (1980);

Danuta Wolfram-Romanowska's (Institute of English Philology UAM) work on *The Perception of British English Stops and Spirants by Native Speakers of Polish* (1981);

Andrzej Pluciński's (Institute of Linguistics UAM) dissertation on *Automaty-*

zacja lokalizacji akcentu w polskiej mowie potocznej na podstawie analizy akustycznej [*Automatizing the Localization of Stress in Spontaneous Speech in Polish on the Basis of Its Acoustic Analysis*] (1983);

Liliana Madelska's (Institute of Linguistics UAM) work entitled: *Mowa spontaniczna. Analiza wariantywności fonetycznej w wymowie studentów Uniwersytetu im. Adama Mickiewicza* [*Spontaneous Speech. An Analysis of Phonetic Variation in the Pronunciation of the Adam Mickiewicz University Students*] (1987); and

Paweł Nowakowski's (Institute of Linguistics UAM) dissertation: *Wariantywność współczesnej polskiej wymowy scenicznej* [*The Veriability of Contemporary Polish Stage Pronunciation*] (1995).

For some years Maria Steffen Batóg has been actively engaged in strenuous editorial work. In 1987 she co-edited the first issue of "Studia Phonetica Posnaniensia". The consecutive issues were published in 1990, 1993, 1995 and 1996.

The staff of the Department of Phonetics underwent several changes during the last two decades. The reader may have already noticed that the University administration has never been particularly keen on stabilizing the small but vigorous community of Poznań phoneticians. Fortunately, the adversities seem to have had little influence on the cooperative spirit and high quality of work so characteristic of the group. The reader may find more information on the history of phonetic research in Poznań (from the early seventies onwards) in Maria Steffen-Batóg's paper MSB 14.

At present the staff of the Department are: Andrzej Pluciński, Ph.D., Paweł Nowakowski, Ph.D. and Aleksandra Iłowiecka. Doctor Pluciński's works deal among others with algorithms of stress recognition in everyday speech, with automatization of the speech signal representations, and with the normalization of the speech signal spectrum (Pluciński 1978, 1983, 1987). Paweł Nowakowski has been working on some aspects of carefully spoken Polish (so-called stage pronunciation). He is also a co-author of a paper on an algorithmic approach to phonetic transcription (Nowakowski 1993).

Several other linguists have worked in the Department of Phonetics. They include: Katarzyna Dobrogowska, Lutosława Richter, Liliana Madelska, Piotra Łobacz, Jacek Konieczny, Małgorzata Witaszek-Samborska, Waldemar Iłowiecki, and Olga Matuszkina.

On the other hand, phonetics and phonology have been also studied in other Departments of the Institute of Linguistics, UAM. Professor Jerzy Bańczerowski, for instance, has published numerous papers on various aspects of theoretical phonology. Also Professor Piotra Łobacz — whose research at the moment includes some aspects of psycholinguistics (psychophonetics, in particular), and analyses of bio-cybernetic and bio-medical systems as well as artificial intelligence — published some years ago several papers on acoustic phonetics and phonetic statistics.

Summing up the introductory section, I would like to subdivide Maria Steffen-Batóg's works — all of which deal with problems of phonetics — into three groups:

1. Statistical phonetics. Phonetic distance. History of phonetic studies.
2. Transcription algorithms.
3. Prosody of the Polish language.

The last group would encompass her analyses of two types of problems, namely: the intonation system and the perception and physical manifestations of stress.

In her research work, Maria Steffen-Batóg has turned out more than once to be a forerunner of new trends and methods of phonetics in Poland (MSB 1, 4, 16). In all those cases the conceptual and theoretical apparatus worked out in her monographs conformed to the highest theoretical and methodological standards. It should also be stressed at this point that all her works are — on the one hand — grounded in solid experimental research and — on the other — they all find direct practical applications.[2]

1 Statistical Phonetics. Phonetic Distance. History of Phonetic Studies.

The paper MSB 1 is one of the most important studies on statistical phonetics ever carried out in Poland. I must also point out here the fact that it is the first analysis of the frequency of occurrence of speech sounds in the Polish language.

The author analysed a series of continuous written texts (written mainly in the fifties). The texts were examples of either literary, scientific or journalistic written Polish and they came from ten distinct sources. A fragment of each text which consisted of 5000 consecutive sounds was analysed. Thus, the analysed material (and the author made all her calculations without the help of any machine) consisted of 50 000 sounds. The texts were transcribed so as to conform to the pronunciation

[2] A collection of selected most important Maria Steffen-Batóg's papers has been published in 1997: *Phonetic Studies*. Poznań: Wydawnictwo SORUS, 139 pp. The collection contains the following papers: MSB 1, 3, 13, 17, 19, 20, 40.

of educated Poles with the Warsaw dialect background. First, the frequency of occurrence of individual sounds was determined for each text separately until all the 5000 sound long texts have been analysed. Then similar data were calculated for sums obtained through the addition of consecutive texts. The results showing the frequency of occurrence of each sound became more and more stable with the growth of the material analysed. Finally the standard deviation was determined for the occurrence frequencies of the individual sounds. The deviation was relatively small (0.004% – 0.1%).

I would like to present below — in a maximally condensed form — some of the results arrived at in this paper.

1. The Polish language seems to be a prevalently consonantal one. The frequency of occurrence of consonants (including semivowels) equals 59.9% [for vowels it is 40.1%]. It was also proved that the discrepancy is significant as it is independent of the choice of the material analysed.

2. The occurrence frequencies for the Polish vowels were determined to be respectively:

i	3.9%
y	4.1%
e	10.2%
a	9.2%
o	8.6%
u	3.4%

Thus the highest vowels were found to be the least frequent ones. The frequency of a given vowel (with the exception of [a]) grows with the growth of its degree of openness. The front vowels ([i], [y], [e]) are more frequent (18.2%) than the back ones (i.e., [u] and [o] — 12.0%). Naturally, if one includes [a] with the back vowels, the disproportion would decrease (the front vowels — 18.2% , as against 21.2% — for the back ones).

3. The occurrence frequencies of fricatives, stops and sonorants (nasals, liquids, etc.) seem to be similar and they are, respectively, 15.6%, 16.4% and 15.9%. Affricates (6.7%) and semivowels (5.2%), on the other hand, are clearly much less frequent than the former three types.

4. Within the group encompassing stops, fricatives and affricates (whose joint frequency is 37.1%), voiceless sounds are more frequent (24.1%) than voiced ones (13%). The domination of voiceless sounds is preserved for all the pairs within the group which stand in the relation of opposition: voiced vs. voiceless (with the

exception of the [f] – [v] pair). The disproportion, however, is particularly striking in the case of the [ǯ] (0.012%) – [č] (1.2%) pair.

In her conclusions, the author writes (MSB 1, pp. 163–164):

> The aim of the present paper was to determine the frequencies of occurrence of individual speech sounds of the Polish language and thus, to show their greater or lesser importance for the language system. It is rather evident that with the growth of the frequency of occurrence of speech sounds, their importance for a given language system grows, whereas variants of phonemes which rarely occur in some language are of lesser importance for the characteristics of the system. Naturally, particular distributions of the occurrence frequencies of individual speech sounds within a given language can be partially accounted for by means of referring to the historical development of that language (and/or the development of the proto-language from which the language has its source). Thus, historical arguments could be used to partially explain why the vowel *e* is relatively frequent in Polish or why we face the large disproportion between the occurrence frequencies of Polish [č] as against [ǯ]. Also the reverse proportions of the frequency of occurrence of *f* and *v* could be understood, if one remembers that *f* as an independent phoneme entered the phonetic system of Polish relatively late. However, all these detailed facts, pertaining to historical phonetics fall outside the scope of this paper. Similarly outside its scope remain the quantitative relations characteristic of the south-western variety of Standard Polish and the same relations pertaining to the regional dialects of the language. Concerning the south-western variety of Polish, a quantitative analysis would most probably contribute nothing baffling to what I present in this paper (the frequency of occurrence of voiceless consonants would turn out to be slightly lower, as a result of the tendency of voicing in certain cases the consonats in the final position, which is characteristic of the variety). Yet, as far as regional dialects are concerned, a detailed quantitative analysis would most certainly show a different distribution of the occurrence frequencies of individual sounds (particularly, as a result of such phenomena as the identification [in the north of Poland] of the *i* – *y* speech sounds, which are distinct in Literary Polish, and the identification of the fricatives [s,z,c,ʒ] with the affricates [š,ž,č, ǯ], [in the Mazurian dialects]).

The research initiated by Maria Steffen-Batóg resulted in a series of studies undertaken by among others W. Jassem, P. Łobacz and B. Rocławski (Jassem and Łobacz 1976, Rocławski 1976, 1981). As I have mentioned before, the paper MSB 1 has been quoted by dozens of authors in many papers, monographs and handbooks (see, for instance, Dukiewicz 1967, Segal 1969, Wierzchowska 1980).

The results obtained in MSB 1 were used in two other early papers of Maria Steffen-Batóg (MSB 2, 3) which were published before her Ph.D. dissertation and which were important for practical reasons.

Thus, MSB 3 is an extremely simple introduction to problems pertaining to the construction of tests for the investigations concerning the identification and discrimination of speech sounds. The results of such identification and discrimination studies would be important for various branches of both science and technology (they could be of considerable value to medical, transmission and telecommunication studies and also to architectural acoustics). In audiometry, for instance, the tests could be used to determine the degree of hearing impairment (or loss) and they would then help the patient to find an appropriate hearing aid. Then, as the quality of transmitted voice messages depends mainly on the quality of the equipment used for the purpose, empirically verifiable tests are needed to determine the necessary quality norms (for both the equipment and the messages). Finally, linguistic tests may be used by the architect in all those cases where sound perception and reception are of primary importance (e.g. lecture halls, theatres, concert and parliamentary halls, conference rooms, churches, and so on).

MSB 3 was published in a periodical devoted to telecommunication problems. Thus, the author first discusses — briefly and lucidly - several linguistic terms (word, speech sound, phoneme, phonetic and phonemic transcriptions) which the reader will have to understand to be able to follow the methodological principles presented later on in the paper (on which the construction of her linguistic tests is based).

Both the tests consisting of meaningful units (e.g. words) and the "meaningless" logatomic tests must fulfill a number of conditions to be regarded as representative samples of a given language. A test which fulfills all the conditions is called a phonetically (or phonemically) balanced test. A balanced test is defined by the author in the following way (MSB 3, pp. 85–87):

> A test may be regarded phonetically balanced if the proportion (percentage) of individual speech sounds and of their combinations in the test is the same as the percentage of the same speech sounds and combinations in the language for which the test has been constructed. Mainly for practical reasons, the phonetic balance is usually replaced by the phonemic balance. In the latter case, attention is paid to maintaining the proportions of the frequency

> of occurrence of phonemes rather than the proportions of individual speech sounds. ...
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> Keeping the frequency of occurrence balance with respect to combinations of speech sounds or phonemes should by no means be regarded as less important than maintaining the same balance for individual sounds or phonemes. It should be remembered that — in addition to a given set of speech sounds and phonemes, each of which is characterized by some definite occurrence frequency — every language has a number of language specific rules which define the ways in which those sounds or phonemes can be linked together to form higher rank units, such as the syllable, the word or even the phrase (strings of sounds found between two pauses). Phrases may, but do not have to be identical to sentences in the grammatical sense of the term. ...
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> Words in Polish differ considerably with respect to their structure. The differences consist among others in different numbers of syllables and phonemes a single word may be composed of and also in the order of the vocalic and consonantal phonemes which follow one another. As the structure of individual word types and their occurrence frequencies are as much language specific as the occurrence frequencies of individual speech sounds, a properly constructed language test would also have to account for the statistical data pertaining to that range of problems. ...
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> Maintaining the occurrence frequency balance between various word types — particularly in semantically oriented tests — is especially important in view of the fact that — as evidenced by recent research — with the growth of a word's length its intelligibility grows too.

Then, Maria Steffen-Batóg goes on to list a number of additional conditions which should be satisfied while constructing a test. Her conditions stipulate:

— that the size of the test should be adequately chosen,

— that in testing the same subjects, tests should not be repeated,

— that in word-tests, the most frequent words which belong to the basic vocabulary of every native speaker of a given language should be used,

— that it should not be possible for the subject to guess in advance the pronunciation of the units of which the test consists,

— that the tested subject's reaction depends only on what he or she can actually hear,

— that the reactions we expect of the subject are independent of his or her intelligence, education and experience.

The paper ends with some examples of logatomic lists which are balanced in various degrees.

MSB 2 was the last paper (written together with W. Jassem and B. Piela) in which the author used the name of Maria Steffen. The paper again discussed a number of problems of a rather practical nature. It dealt with audiometry, with the construction of instruments for phonetic research (mainly for speech analysis and synthesis), with speech transmission, and with speech recognition in "paranormal" situations (at high altitudes, produced through gas and oxygen masks, etc.). The authors specify in the paper the average spectral distribution of energy characteristic of Polish speech. On the basis of the results obtained in MSB 1, three phonetically balanced word lists were used (which differed with respect to their length). Next the average spectra of the three lists were analysed and the analyses showed that the shortest (of 21 words) was quite sufficient to obtain statistically valid results.

Unlike the previously discussed papers, MSB 20 (written together with Tadeusz Batóg) is primarily theoretical in nature. Its goal is to define the notion of phonetic distance, which would additionally satisfy certain naturalness conditions. Such a phonetic distance would be a numerical measure of the difference between units of a sound system (i.e. speech sounds or phonemes). Many linguists tried to determine the measure in various ways and their approaches are presented briefly in the opening section of the paper. The general idea was to assign the numerical values of some set of pre-determined parameters (characterizing speech sounds) to those speech sounds and then to find the distance between the speech sounds with the help of some mathematical operations on these values. The phonetic units are treated as if they were vectors and the distance between them can be calculated by comparing the coordinates of the vectors.

Maria Steffen-Batóg and Tadeusz Batóg introduced a different approach to the problem of phonetic distance in the paper. It was based on the mathematical theory of multilevel classifications which had been developed in two papers written jointly by Tadeusz Batóg and Seweryna Łuszczewska-Romahnowa (TB 9, 10). The two papers analyse generalized classifications of a transfinite type. Yet for the purposes of MSB 20, the approach could be restricted only to n-level classifications, where n is a natural number.

We shall call the sequence $F_1, \ldots, F_n$ of classifications of the set X the *n-level classification* of that set if and only if $F_1 = \{X\}$ and for all indices i, j: if $i < j \leqslant n$, then for every set $Y \in F_j$ there exists a set $Z \in F_i$ such that $Y \subseteq Z$.

Thus, an n-level classification of a set is a sequence of such classifications of the set where each consecutive classification is "smaller" than the directly preceding one. Classifications of that kind have been commonly used in all taxonomic studies. The authors quote a biological taxonomy as an example (MSB 20, p. 52):

> The following are actual examples drawn from the science of biology. According to A. Wetmore's division of birds there are more than ten orders. However, the *Gaviiformes* order comprises only one family called *Gaviidae* and the latter, likewise, comprises only one genus of *Gavia*. It is only the species that are more numerous: *Gavia stellata, Gavia arctica, Gavia immer, Gavia adamsi*, etc. Analogically, the order of *Podicipediformes* comprises only one family of *Podicipedidae*, which further splits into several genera. The order of *Charadiiformes* is composed of a considerable number of families, e.g. the *Recurvirostridae*. The latter divides into four genera, one of which is *Recurvirostra*, which in turn comprises merely one species, i.e. *Recurvirostra avosetta*.

The example was quoted to illustrate the fact that in multilevel classifications there may exist sets of objects which are simultaneously members of classifications from various levels.

Trees are a convenient graphic form used to present multilevel classifications — the individual levels of a tree correspond to consecutive classifications and the nodes of a single level correspond to the members of a classification which the level represents.

For an arbitrary set X, for its n-level classification $F_1, \ldots, F_n$, and for any elements x, y, of the set X, we can now determine the similarity index of the elements x and y (with respect to the n-level classification $F_1, \ldots, F_n$). That similarity index — which will be denoted by $I(x, y)$ — is the greatest number i such that both x and y still remain elements of the same member of the classification F_i (in other words, it will be the number of the last level at which x and y satisfy the conditions specified above). Now, the distance between x and y (with respect to $F_1, \ldots, F_n$), denoted by $D(x, y)$ can be defined with the help of the following equation:

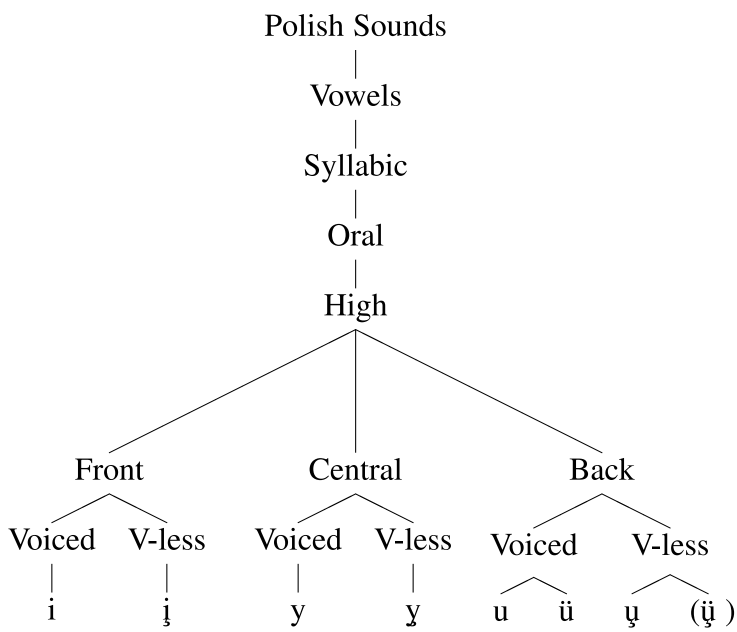
$$D(x, y) = n - I(x, y)$$

The value of $D(x, y)$ — defined in the way suggested above — is non-negative, the distance between x and x (the distance of x from itself) equals 0, the distance between x and y is the same as the distance between y and x, and for any x, y, z: the sum of distances between x and y on the one hand and between y and z on the other is not smaller than the distance between x and z. Furthermore, if every member of the last classification level (that is, of F_n) is a one-element set, then the following equivalence holds:

$$D(x, y) = 0 \text{ if and only if } x = y.$$

In such a case we can say that the set of classified objects is a metric space (in the sense in which the term is used in mathematics).

To show how the apparatus presented above could be used to define distances between speech sounds in Polish the authors first present an eight-level classification of the sounds. The classification is based on articulatory criteria and it closely follows the sound inventory presented in the monograph MSB 16. Below I shall omit the discussion concerning the formal properties which differ the authors' classification from the articulatory classifications put forward by other specialists. Furthermore, to illustrate the approach as succinctly as possible I shall have to perpetrate an act of horticultural-phonological vandalism. Namely, I shall prune the exuberant tree of meticulously classified Polish speech sounds and cut away all the branches which do not lead to the final nodes representing Polish oral high syllabic vowels. Thus, what remains looks like this:



The diagram shows, for instance that

$$D(i, i) = 0 \text{ and } D(i, u) = 3.$$

The approach presented in MSB 20 entails a number of important problems, such as, for instance:

1. Is the notion of phonetic distance discussed here natural? (An answer to the question seems to be related to the problem of ordering properly the consecutive levels, which in turn entails the issue of the "importance" of the features assigned to the classified sounds as the ordering would certainly depend on that);

2. It is impossible to reduce all the classifications of speech sounds in Polish only to natural classifications which would be completely dichotomous. As a result, we get for instance $D(i, y) = D(i, u) = 3$. Intuitively, however, it seems more natural for a front vowel to be more distant from a back vowel than from a central one. Yet to render the intuition formally (within a multilevel classification approach which would at the same time be more natural) does not seem to be an easy matter.

Maria Steffen-Batóg is also the author of three papers in which she discusses the development of acoustic phonetic studies in Poland (MSB 8, 14, 17). Although the beginnings of these studies go back as far as the first decade of the 19th century (to J. Siestrzyński — the author of the first classification of Polish speech sounds based on acoustic criteria; and to A. Wikszemski who took out a patent on a photographic method of registering sound waves (in 1889)), the development of acoustic phonetics only began in Poland in the present century. In MSB 17 the author outlined the development in eight sections. The Introduction and the last section of the paper dealt with, respectively, the organization of the research and its historical contexts and with the publications (handbooks, periodicals and overviews) which aim at the propagation of acoustic phonetics in Poland. In each of the remaining sections, one thematic aspect of the research was reviewed in chronological order. The subject-matter which the author chose to discuss includes:

— the spectral features of speech sounds,
— speech melody,
— word stress and sentence stress,
— duration of speech sounds,
— the voice-distinguishing acoustic parameters of speech,
— automatic speech recognition,
— the construction of instruments for phonetic research.

It might be worth stressing at this point that Maria Steffen-Batóg herself was actively engaged in the research concerning the first five subjects listed above.

These three papers review the results of acoustic phonetic studies in Poland until the mid-seventies. The author evaluated (in 1971) their further perspectives in the following way (MSB 8, pp. 69–70):

The overview of the main achievements of acoustic phonetics in Poland which have been presented above should also be supplemented with a list of problems which will have to be dealt with in the near future. In my opinion, it is most urgent to first come to grips with those phonetic phenomena, which have so far been paid the least attention. That means that we need first of all detailed instrumental analysis of utterance intonation in Polish. The research into these problems carried out so far can hardly be said to have gone outside its preliminary stage. Then, I also think it necessary to supplement the spectral analyses of Polish speech sounds and their combinations with detailed studies of spectral properties of consonantal clusters. Further investigation should also be carried out into the acoustic parameters determining the correct recognition of individual sounds and their combinations. Finally, we urgently need the continuation of the research that began some time ago on the acoustic parameters which make it possible to identify individual voice features. A solution of the latter problem would be important not only from a purely phonetic point of view, but also on account of its extra-linguistic applications.

2 Transcription Algorithms

Maria Steffen-Batóg has so far dealt with the problems of the construction and properties of transcription algorithms in the following works: MSB 12, 13, 15, 16, 18, 30 and MSB 32.

As I mentioned earlier the author was the first linguist to construct transcription algorithms for the Polish language. So far she has constructed the following algorithms:

— an algorithm for phonemic ("broad") transcription (MSB 12, 13, 15, 16),

— a preliminary algorithm for converting phonemized texts (i.e. broad transcriptions viewed as texts) in Polish into their orthographic equivalents (MSB 18 written together with Tadeusz Batóg),

— an algorithm for converting phonemic transcriptions of Polish orthographic texts into their phonetic equivalents (MSB 30),

— an algorithm for converting phonetic transcriptions of Polish orthographic texts into their phonemic equivalents (MSB 30),

— an algorithm for phonetic transcription of orthographic texts in Polish (MSB 32, together with Paweł Nowakowski).

The benefit of having transcription algorithms worked out should be obvious. Let us list by way of an example two of their many possible applications:

— transcription algorithms are of fundamental importance for studies on speech synthesis,

— transcription algorithms are essential for constructing human — machine communication systems (and the application of those systems is in turn practically unlimited).

The construction of a single algorithm is typically beset with various difficulties both at the stage of data collecting and at the stage of working out individual transcription rules. The general principles, however, underlying the construction itself seem to be very similar. Hence one successful implementation of such an algorithm in the form of a properly functioning computer program (and such programs have already been written, on which I shall have something more to say below) is a good omen for similar programs based on a series of algorithms modelled on the tested one.

An important characteristic of all the algorithms mentioned above is their universality — they are applicable to all texts of a predetermined variety of Polish. Thus the algorithms attempt to admit of no exceptions, they take into account any possible situation in a given variety of the language. If the author were to ease the restrictions (by means of, for instance disregarding all the cases, the probability of occurrence of which in Polish texts is slight), the algorithms could be drastically simplified. In the papers I quoted above, she certainly points to the fragments of rules which had to be introduced to account for the marginal cases, yet the universality principle is nowhere abandoned.

The so called transcribing function is found at the core of each algorithm. It transforms words rendered in one alphabet (e.g. traditional orthography) into their equivalents expressed in a different alphabet (for instance, a phonemic one). The function is defined by means of a set of formal transcription rules which are worked out one by one for every single sign of the initial or input alphabet. The rules must in turn refer to the immediately preceding and following contexts of the transcribed sign.

In what follows below, I would like to confine my presentation of the seven works by Maria Steffen-Batóg to the following:

1. some remarks on the principles underlying the preparatory work on orthographic texts before they can be phonemically transcribed;

2. a brief discussion of the principles of formulating transcription rules;

3. quoting — by way of an example — some chosen transcription rules which convert Polish orthographic texts into phonemically transcribed texts (the quote

comes from MSB 16);

4. giving a similar example which will this time concern an algorithm for converting phonemic transcriptions into orthographic texts (based on MSB 18 — a paper co-authored by Tadeusz Batóg);

An orthographic text in Polish — before it can undergo a process of automatic transcription — must satisfy a number of firm conditions. Maria Steffen-Batóg lists in her works the following prerequisites:

1. An orthographic text must be written down completely in some predetermined alphabet. In particular, all numbers should be replaced therein with their verbal equivalents (for obvious reasons).

2. At the beginning of a text a special sign should be placed to mark that what follows is a beginning of a word.

3. The end of a transcribed text should also be marked (by means of some punctuation mark, for example).

4. One must determine the speech tempo of the text which is to be transcribed.

5. All loan-words and loan-phrases whose spelling has not yet been adapted to Polish orthography should be removed from the whole text.

6. All abbreviations must be replaced by their word counterparts.

7. Some words must be divided in certain places with the help of a special separator. This is necessary to distinguish the pronunciations of such words as for instance *zamarzać* (frequentative of *zamorzyć* "to starve") as against *zamarzać* (perfective of *marznąć* "to freeze"). The list of words to be divided should be attached to the set of transcription rules.

I must add at this point that the conditions are strictly language dependent. Their list quoted above refers to such specific characteristics of Polish as its complex inflectional system, sandhi processes and many-to-one relations between letters and speech sounds. It is almost certain that for some other language a set of different conditions would have to be postulated.

Maria Steffen-Batóg's transcription algorithms are exceptionally simple and elegant. The simplicity and elegance result from — among other factors — the fact that the author made use of the formal apparatus of the algebra of sets and the algebra of words. Thus, before I present her general principles underlying the formulation of the transcription rules, I will have to remind the reader some of the basic set theoretical terms she refers to in her approach.

Let us assume that X and Y stand for two given finite sets (say, two distinct alphabets; an orthographic one and a phonemic one, respectively). If α and β are sign sequences in one of the respective alphabets, we may represent the concatenation of the two sequences simply as $\alpha\beta$. The operation of concatenation is associative, and the empty word (denoted by the symbol 1) is its neutral element. The operation of concatenation may be now extended to sets of words. If Γ and Δ are sets of words (over the fixed alphabet), then the concatenation of the sets results in the set $\Gamma \cdot \Delta$ consisting of all and only those words of the form $\alpha\beta$, in which $\alpha \in \Gamma$ and $\beta \in \Delta$. Instead of $\{a\} \cdot \Gamma$, we shall write briefly $\alpha\Gamma$. The symbols: $\Gamma \cup \Delta, \Gamma \cap \Delta$ and $\Gamma - \Delta$ will denote, respectively, the results of set theoretical operations of union, intersection, and difference as applied to the sets Γ and Δ. Naturally, the operation of the concatenation of sets of words as well as the three set theoretical operations mentioned above are governed by various laws well known in the field of arithmetic (e.g. concatenation is associative and its empty word is the neutral element, concatenation is distributive with respect to both the sum and difference of sets). Thus, "calculations" can be made on the sets of words in a similar way as in arithmetic. We shall denote by X^* the set which consists of all the words formed from the elements of a given alphabet X.

Transcription rules define how to transcribe individual (orthographic, in our example) letters with respect to the type of environment in which they occur in the words to be transcribed. All such rules are drawn up in the form of the so called table of transcription rules for a given letter. Such a table has the following form:

α	Δ_1	Δ_2	$\cdots$	Δ_k	$\cdots$	Δ_m
Γ_1	$\beta_{1,1}$	$\beta_{1,2}$	$\cdots$	$\beta_{1,k}$	$\cdots$	$\beta_{1,m}$
Γ_2	$\beta_{2,1}$	$\beta_{2,2}$	$\cdots$	$\beta_{2,k}$	$\cdots$	$\beta_{2,m}$
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
Γ_i	$\beta_{i,1}$	$\beta_{i,2}$	$\cdots$	$\beta_{i,k}$	$\cdots$	$\beta_{i,m}$
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
Γ_n	$\beta_{n,1}$	$\beta_{n,2}$	$\cdots$	$\beta_{n,k}$	$\cdots$	$\beta_{n,m}$

The symbol α in the upper left corner of the table means that the rules defined by that table refer to the letter α. Moreover, the following relations hold:

$\alpha \in X,\ \Gamma_i \subseteq X^*,\ \Delta_k \subseteq X^*,\ \beta_{i,k} \in Y^*$ (for all i, k such that $1 \leqslant i \leqslant n, 1 \leqslant k \leqslant m$).

That means that:

— the rules (of our table of transcription rules) refer all to the transcription of the letter α from the (orthographic) alphabet X into the (phonemic) alphabet Y.

— the headings of the columns, that is $\Delta_1, \ldots, \Delta_m$, list the various types of following (orthographic) contexts in which the letter may appear and which may influence the way it is transcribed;

— the headings of the lines of the table, that is $\Gamma_1, \ldots, \Gamma_n$, describe in turn the types of preceding (orthographic) contexts in which the letter to be transcribed may appear and which have influence upon its transcription;

— at the intersection of a given column with a given line we find a word of the Y (phonemic) alphabet which defines the transcription of α in a given environment (in other words: every time α is found in the context $\Gamma_i \alpha \Delta_k$; i.e. whenever α immediately follows some word γ which belongs to the set Γ_i and at the same time whenever it immediately precedes some word δ belonging to the set Δ_k it should be transcribed in the form of the word $\beta_{i,k}$.

Before I get to the examples which will illustrate the transcription rules for the actual letters of the Polish (orthographic) alphabet, I would like to reflect for a moment on some problems of a methodological nature, namely on the adequacy and coherence of the tables of transcription rules. Their adequacy and coherence seem to consist in satisfying certain conditions whose nature is both formal and empirical. The author defined those rules in the following way (MSB 16, pp. 70–75):

> We shall say that the table of transcription rules for the letter α — which has the form shown in the diagram above — is *columnwise inconsistent* if and only if there exists such set $\Sigma \subseteq X^*$ and also there are indices k, r, i, such that: $1 \leqslant k \leqslant m, 1 \leqslant r \leqslant m, 1 \leqslant i \leqslant n, \Delta_k \cap (\Delta_r \cdot \Sigma) \neq \emptyset$ and also $\beta_{i,k} \neq \beta_{i,r}$.
>
> We shall say that the table of transcription rules for the letter α is *linewise inconsistent* if and only if there exists a set Ω, such that: $\Omega \subseteq X^*$ and also there are indices i, j, k, such that: $1 \leqslant i \leqslant n, 1 \leqslant j \leqslant n, 1 \leqslant k \leqslant m, \Gamma_i \cap (\Omega \cdot \Gamma_j) \neq \emptyset$ and also: $\beta_{i,k} \neq \beta_{j,k}$.
>
> We shall say that the table of transcription rules for the letter α is *consistent* (or that it satisfies the condition of consistency) if and only if the table is neither columnwise nor linewise inconsistent.

Thus, consistency of the transcription table for a given letter simply requires that the table should contain no two rules which would instruct us to transcribe the letter in two different ways in one and the same context. The consistency condition for tables of transcription rules is purely formal; there is also an effective method of checking whether or not it has been satisfied. What is more, the condition can be replaced with the more rigid yet simpler strong consistency condition (which is still easier to control):

> We shall say that the table of transcription rules for the letter α (of the form shown above) fulfills the *strong consistency condition* (or that it is strongly consistent) if and only if in the set $\{1, 2, \ldots, m\}$ there exist no indices k, r, such that for some set $\Sigma \subseteq X^* : \Delta_k \cap (\Delta_r \cdot \Sigma) \neq \emptyset$, and at the same time in the set $\{1, 2, \ldots, n\}$ there exist no indices i, j, such that for some set $\Omega \subseteq X^* : \Gamma_i \cap (\Omega \cdot \Gamma_j) \neq \emptyset$.

Another condition that each table of transcription rules must satisfy is the completeness condition, which stipulates that the table for a given letter should contain all the rules which account for the transcriptions of the letter in any natural orthographic context characteristic of the letter:

> We shall say that the table of transcription rules for the letter α is *complete* (or that it satisfies the completeness condition) if and only if for any two words φ, ψ such that $\varphi\alpha\psi \in \#X^*O'$ and assuming that $\varphi\alpha\psi$ is a possible fragment of some text in the Polish language, there exist indices i, k $(1 \leqslant i \leqslant n,\ 1 \leqslant k \leqslant m)$ and words $\varphi_1, \varphi_2, \psi_1, \psi_2$, such that: $\varphi = \varphi_1\varphi_2,\ \ \psi = \psi_1\psi_2, \varphi_2 \in \Gamma_i, \psi_1 \in \Delta_k$, and also $\beta_{i,k}$ is some concrete word in the alphabet Y (in other words, the intersection of the i-th line with the k-th column is nonempty).

The sequence $\varphi\alpha\psi \in \#X^*O'$ in the quotation denotes, roughly speaking, the fact that $\varphi\alpha\psi$ is an orthographic word whose beginning is marked by means of the sign # and whose ending must be marked with one of the punctuation marks (including the pause mark) of the specified set of those marks denoted by O' — J.P.

The completeness condition makes an obvious reference to the empirical linguistic reality. To satisfy the condition for all the tables of which her algorithm of phonemic transcription consists must have required of the author a huge amount of meticulous and painstaking work as she had to account for the whole linguistic material of contemporary Polish. Maria Steffen-Batóg based her analysis on the eleven volumes of the *Słownik języka polskiego* [*Dictionary of the Polish Language*], edited by W. Doroszewski. She writes about that fragment of her work with the modesty so characteristic of her:

> The whole process of arriving at the formulation of individual tables of transcription rules was rather laborious. Thus we shall omit here all the details concerning the process itself. The discussion would have to deal with unimportant, in my opinion, technical matters whereas what really counts are the

> final results presented in the form of our tables. We have only mentioned the process of analysis here to inform the reader on what basis we consider our hypothesis concerning the completeness of the set of the transcription rules well-justified.

The last condition imposed on the set of transcription rules presented in the form of transcription tables is the adequacy condition which is to guarantee that they satisfactorily account for the linguistic reality analysed:

> Thus, we shall say that the table of transcription rules (of the form shown above) for the letter α is *adequate* (or that it satisfies the adequacy condition) if and only if for any index i $(1 \leqslant i \leqslant n)$ and for any index k $(1 \leqslant k \leqslant m)$ the letter α is really read as $\beta_{i,k}$ in every word of the Polish language which has the form $\varphi\alpha\psi$, such that: $\varphi \in \Gamma_i$, and $\psi \in \Delta_k$.

Making all the tables of transcription rules adequate (in the sense defined above) must have called for tremendous effort too (Maria Steffen-Batóg writes: "it was not an easy task ..."). As she could in that case resort neither to intuition (too unreliable) nor to phonetic handbooks (they never account for orthographic rules), she had no choice but to analyse the whole of the Polish language material.

The adequacy condition is stronger than that of consistency, for practical reasons, however, the author decided to leave both (finding that a given table is inconsistent is a simple way of proving that it is inadequate).

The only remaining procedure that has to be applied at this point, before I present some examples of the tables of transcription rules, is the explicit enumeration of all the elements of the Polish orthographic alphabet X, of the Polish phonemic alphabet Y, as well as of some of the subsets of X which correspond to types of orthographic contexts. Thus, we have:

$X = \{$a, ą, b, c, ć, d, e, ę, f, g, h, i, j, k, l, ł, m, n, ń, o, ó, p, r, s, ś, t, u, w, y, z, ź, ż, ., !, ?, , , ;, :, —, –, ..., (,), #, /$\}$.

The following subsets of the X set (the orthographic alphabet) play an important role in the formulation of transcription rules:

$A = \{$a, ą, e, ę, i, o, ó, u, y$\}$
$D = \{$b, d, g, z, ź, ż$\}$
$T = \{$c, ć, f, h, k, p, s, ś, t$\}$
$R = \{$l, ł, r, w$\}$
$M = \{$m, n, ń, j$\}$
$V = A \cup R \cup M$

$O = \{$., !, ?, , , ;, :, —, –, ... , (,), #$\}$
$O' = O - \{\#\}$.
The phonemic alphabet Y is enumerated as follows:
$Y = \{$**p, b, t, d, ḱ, ǵ, k, g, f, v, s, z, š, ž, ś, ź,** χ**, c, ʒ, č, ǯ, ć, ʒ́, m, n, ń, w̃, l, r, j, w, i, y, e, a, o, u, #, !**$\}$.
The letter **#** is a sign denoting a boundary which occurs between two words (a word boundary) and the letter **!** is a transcription sign denoting a pause.
As examples of tables of transcription rules I have chosen two relatively simple tables for the letters y and ż respectively. The first is of the following form:

y	j	A	$X - (A \cup \{\text{j}\})$
Oc	1		**y**
$(X - O)$c	**y**		**y**
O		**j**	**y**
A		**j**	**j**
$X - (A \cup O \cup \{\text{c}\})$	**y**	**y**	**y**

The transcription table for the letter ż consists of two parts. For typographical reasons, we use the following abbreviations in these parts:
$S_1 = (M \cup TD)M$
$S_2 = T(TRA \cup R)$
$S_3 = (D \cup DD \cup M)T$
$S_4 = TD(T \cup K \cup G)$
$S_5 = D(V \cup DV)$
$S_6 = R(A \cup D)$
$S_7 = \{1\} \cup D \cup DD \cup R \cup M \cup TTR.$

ż	S_1	si	TDA	S_2	S_3	S_4
X	**ž**	**ś**	**š**	**š**	**š**	1

The above fragment includes only the transcription rules for ż which do not refer to the preceding context in the texts transcribed. Here, as we can see, columns 4 to 6 contain the same phonemic letter. In all such cases, the author simplifies the table (and makes it clearer) by removing the vertical column lines (except for the headings) and placing only one phonemic letter in the row.
The rest of the table for the letter ż is shown below:

ż	A	S_5	S_6	MA	S_7G	$(T-\{\text{s}\})A$	S_7K
$X-\{\text{d}\}$	**ž**	**ž**	**ž**	**ž**	**ž**	**š**	**š**
#{po,prze,na,o}d	**ž**			**ž**			
{pona,śró,nieo}d	**ž**			**ž**			
# d	1	1					
$(A-\{$o,a,e,ó$\})$d	1						
$(X-\{$#,p,e$\})$od	1				1		1
$(X-\{$n$\})$ad	1	1			1		1
$(X-\{$z$\})$ed	1		1				
$[X-(A\cup\{$#$\})]$d	1			1	1	1	1

Each table of the several dozens worked out by the author in her monograph MSB 16 is supplemented by pertinent comments. We are obviously unable to quote them here. I would like to cite instead the words with which Maria Steffen-Batóg concludes the monograph (MSB 16, pp. 129–130):

> The significance of the results obtained here seems to lie in the following two facts: first of all, the monograph offers a solution of an important and interesting scientific problem and so, its findings have autonomous cognitive value. Yet, more importantly it opens up encouraging perspectives to marked progress in the research on the statistical phonemic structure of the Polish language. The results would make it possible to use quick electronic calculating machines in such studies. I would also like to mention one other advantage, namely the fact that all the transcriptions worked out in conformity with the algorithm presented here will be — theoretically at least — faultless, as all the potentially serious difficulties will have to be overcome at the initial stage by the editor preparing a given text for transcription. Thus, it is to be expected that the results of the automatic transcription process will never need any man-made corrections. Consequently, a hypothetical computer transcription program can be directly coupled with other computer programs, which will in turn allow the machine to make incessant calculations from the moment it is fed an orthographic text until it comes out with the expected results of statistical-phonemic calculations.

As I have already said, the algorithm for phonemic transcription was very soon implemented in the form of appropriate computer programs. One of the most recent implementations (a program for the personal computer) was discussed in Ignacy Nowak's paper (Nowak 1995). Some of the earlier programs (Warmus 1973, Bolc and Maksymienko 1981) were designed for mainframes such as

ODRA 1024 (e.g. Warmus' program written in Algol) or Cyber-73 (Bolc and Maksymienko's programs written in Fortran). The latter series of programs were designed to deal not only with the algorithm for phonemic transcription (whose theoretical bases were presented above) but also with an algorithm for the statistical analysis of phonetic data. Here is what the authors have to say on the implementation of the former algorithm (Bolc and Maksymienko 1981, p. 48):

> The phonemic transcription module was tested on a relatively large number of orthographic texts, comprising altogether about 220 thousand signs. The test was worked out by Professor M. Steffen-Batóg. While processing the data, the program times pointed out an absence of an adequate rule for some letter occurring within a particular context only a few times. For example, a rule was absent for the word *sinice* [blue-green algae, *Cyanophyta*] which would account for the transcription of the letter s in the context [#; ini].
>
> Similarly, the program signalled the lack of an appropriate rule for all such words — starting with the letters c, ć, d, i, r, s, ś, u, w, z, and ż — which were immediately preceded by the opening (left hand) parenthesis. In that particular case, however, the signal was a result of our misinterpretation of the definition of the word treated as an element of the set #C. On the other hand, it should be stressed here that — with the exception of the few cases — the language material used for the test confirmed the accuracy and linguistic adequacy of the transcription rules formulated in the algorithm. The few inadequacies which the program pointed out posed no serious problems and they were corrected by Professor M. Steffen-Batóg. All the changes were however of a local nature and they concerned an insignificant part of the whole. The general adequacy of the results obtained by means of the computer program was also confirmed by an expert linguist (that is by Professor M. Steffen-Batóg).
>
> The speed at which the transcription algorithm worked on the tested material reached about 340 phonemes a second (which contrasts favourably with the speed of M. Warmus' program: 10 phonemes a second).

In yet another program which implemented the phonemic transcription algorithm (Chomyszyn 1986; the program was written in Pascal for the mainframe Mera-400), an inventive representation of the rules was introduced (a directed graph or a tree). Here is how the author himself perceives the advantages of the method (Chomyszyn 1986, p. 280):

> . . . one can suppose that the speeds of Warmus' and Bolc's programs were alike whereas the optimization of the program described in this article (it

> is about eight times faster than the others), was obtained by the different solution method and not by the superior speed of the computer used. The next advantage of compiling the rules to the trees of left and right contexts, is a separation of the rules from the program. It causes the program to be easily transported to other computers. The rules exist also in a form appropriate to the one described by Steffen-Batóg, which allows for modifying them if necessary.

In the long paper MSB 18 (written together with Tadeusz Batóg) the problem of converting Polish phonemic texts into the corresponding orthographic ones was examined (and solved). The issue itself is in a sense dual to the (above presented) problem of making the phonemic transcription of orthographic texts automatic. Consequently, the theoretical basis underlying the two complementary algorithms would have to be the same. The authors of MSB 18, however, had to cope with a number of additional and quite new problems.

To make the transformation of Polish phonemic text into their orthographic equivalents fully automatic and at the same time faultless one has to solve first such questions as for instance that of the equivocal phoneme-letter correspondence (compare such homophones as e.g.: *tępo — tempo, może — morze, konta — kąta*) or that of the contextual dependence of pronunciation (e.g. contextual voicing or devoicing of consonants in word final positions [before a pause], which depends on whether the consonant with which the following word begins is voiced or voiceless — e.g. *kod — kot, snob — snop, stóg — stuk*). The algorithm constructed by the authors does take account of the indeterminacy by enumerating precisely all the variant spellings. Thus, for instance, the notation *st(ó+u)(g+k)* denotes that the third and fourth positions may be filled with either *ó/u* or *g/k* respectively.

The operation of the algorithm consists in the first place in analysing the neighbouring phonological contexts — its rules are orthographic rules for rewriting consecutive phonemes of a given phonemic text based exclusively on the form of the preceding and following contexts (vowels and pauses form context boundaries).

I shall not give any examples of the rules here. Instead, I would like to show the results of the implementation of the algorithm quoting a fragment of the authors' example after MSB 18. As the source orthographic text they used a fragment of page 127 from the book by J. Hawryluk entitled *Maszyna cyfrowa — narzędzie człowieka współczesnego* [*Digital Computer — Modern Man's Tool*] (Warszawa 1974). The source text was first transcribed phonemically (with the help of the algorithm described in MSB 16) and then the output phonemic text was used as the input text for the conversion algorithm worked out in MSB 18 (MSB 18, pp. 90–91):

> “SOURCE ORTHOGRAPHIC TEXT
>
> Urządzenia słyszące i rozpoznające dźwięki mowy ludzkiej działają również na zasadzie przechowywania w pamięci pewnych wzorców. ...
>
> [The work of the devices which are capable of listening to and recognizing the sounds of human speech also consists in storing certain patterns or models in their memory.]
>
> Phonemic text
>
> **użonz̦eńa swyšonce! i rospoznajonce ź̦vjenḱi movy lućkej! ź̦awajow̃ ruvńeš! na zasaź̦e pšeχovyvańa f pamjeńci! pevnyχ vzorcuf!** ...
>
> Algorithmically produced orthographic text
>
> u(ż + rz)(o + ą)(1 + n)dzenia słysz(o + ą)(1 + n)c(e + ę), i ro(s + z)poznaj(o + ą)(1 + n)c(e + ę) dźw(i + j)(e + ę)(1 + n)ki mowy l(u + ó)(c + dz)kiej, działają r(u + ó)wnie(sz + ż + rz), na zasadzi(e + ę) p(sz + rz)e(ch + h)owywania w pami(e + ę)(ń + n + 1)ci, pewny(ch + h) wzorc(u + ó)(f + w + ff),”.

The authors comment on the results of their micro-experiment as follows:

> The phonemic text consisted altogether of 887 occurrences of distinct phonemes and we naturally disregard here the phonemic symbols (letters) **#** and **!**. Out of that number of phonemes 680 were rendered unequivocally and correctly in the output orthographic text produced with the help of our algorithm. The algorithm however was unable to determine unequivocal representations for the remaining 207 phonemes. The positions corresponding to those 207 phonemes were thus filled in with a list of choices, each of which does include — in addition to clearly wrong representations — one correct orthographic rendering of a particular phoneme.
>
> Statistically, the results are as follows: 77% of phonemes were assigned unequivocal and quite correct orthographic representations, whereas 23% of phonemes were rendered equivocally in the form of lists of variants. Taking

> into consideration the fact that our study has been the first attempt at coping with the problem, and that the algorithm we arrived at is of a preliminary nature, one must come to the conclusion that the results of our experiment are quite satisfactory and they may stimulate further research.

The authors close their paper by pointing out the ways of making their algorithm more effective.

3 Prosody of the Polish Language

Maria Steffen-Batóg has shown broad interest in studying prosodic categories since the beginning of her academic career. The works dealing with certain prosodic aspects of the Polish language (that she has published so far) seem to fall naturally into the following two groups:

— papers treating of various aspects of intonation (MSB 4, 6, 7, 10, 11); and

— works on stress perception and on the physical manifestations of stress (MSB 5, 19, 21, 23, 24, 25, 27, 28).

3.1 Intonation

The author of the present review has always very highly valued the paper entitled *Versuch einer strukturellen Analyse der polnischen Aussagemelodie* (MSB 4), which — as we remember — is a synopsis in German of Maria Steffen-Batóg's Ph.D. dissertation (defended in 1963).[3]

As in the case of her phonostatistical studies (MSB 1) and in the case of her work on making phonemic transcription automatic (MSB 16), Maria Steffen-Batóg's dissertation is again a pioneer work — it is the first comprehensive study of the intonation system of the Polish language. The pioneering nature of her work may have been one of the reasons why the author paid such meticulous attention to methodology. Her study is based on auditory analyses of language data. For monitoring purposes, however, a part of the material was also subjected to instrumental — primarily spectrographic — analysis.

All the terms used by the author in her dissertation have been clearly and explicitly defined in terms of (a very small number of) basic terms of acoustic

[3]The full (revised) text of Maria Steffen-Batóg's Ph.D. has been recently published under the title *Struktura przebiegu melodii polskiego języka ogólnego* (*The Structure of Speech Melody Sequences in Standard Polish*). Poznań: Wydawnictwo SORUS, 1996, 202 pp.

phonetics. That is why the work may be regarded as adequately prepared to be transformed into a fully formalized description of the respective class of language phenomena. Making a logical reconstruction of Maria Steffen-Batóg's approach would — in my opinion — require nothing more than reading the text carefully, writing down the consecutive solutions the author arrives at, and translating them into some chosen formalized language (naturally, one would also have to list explicitly all the primitive terms, the assumptions made, and so on).

The aim, however, which the author sets herself does not consist in a logical reconstruction of some ready-made linguistic theory (as before 1963 very few studies dealt with the intonation system of Polish; Maria Steffen-Batóg can quote only the works of Wóycicki, Dłuska, Mayenowa, Wodarz and Jassem), she rather wanted to create a theoretical apparatus which would be adequate first of all to empirical research. In the course of her research the author established the structure of the intonation system of the Polish language. The fundamental notion defined in the dissertation is the notion of an intoneme, characterized distributionally by means of the notion of functional equivalence of tonal units. The work presented the inventory of Polish intonemes and the distinctive features differentiating them.

The linguistic data on which the work was based were taken from everyday speech, fragments of literary works, of radio broadcasts, lectures, speeches and talks.

The basic phonetic terminology used in the work includes the following terms: a phonetic segment, a zero segment, a phonetic phrase, a phonetic syllable and the tone height (or pitch). Maria Steffen-Batóg defines the terms as follows (MSB 4, p. 401):

> Unter einem phonetischen Segment wird hier ein Aussageabschnitt verstanden, dem ein Artikulationskomplex aller Sprechorgane entspricht.
>
> Alle mit dem Gehör wahrnehmbaren Pausen, die innerhalb der Aussagen auftreten, sowie Momente der Stille, die den Aussagen vorangehen bzw. ihnen folgen, bezeichnen wir mit dem Namen Nullsegmente.
>
> Jeden maximalen zwischen zwei sukzessiven Nullsegmenten stehenden Aussageabschnitt wollen wir eine phonetische Phrase nennen.
>
> Mit dem Namen einer phonetischen Silbe bezeichnen wir in Einklang mit der von K.L. Pike formulierten Definition eine Einheit, die aus einem oder mehreren phonetischen Segmenten besteht und die durch einen einzigen von der Lunge stammenden Impuls sowie einen einzelnen Schallgipfel charakterisiert wird.

> Die Tonhöhe bedeutet hier die Grundfrequenz eines stimmhaften Sprechabschnitts. Bekanntlich hängt diese Frequenz von der Geschwindigkeit der von den Stimmlippen ausgeführten Schwingungsbewegungen ab.

By means of the terms defined above, the author defines her notion of an intonational phrase (MSB 4, p. 402):

> Ist P eine beliebige phonetische Phrase, so wollen wir die Gesamtheit des Tonhöhenverlaufs innerhalb P eine der Phrase P entsprechende intonatorische Phrase nennen; die Phrase P hingegen wollen wir als das phonetische Fundament jener intonatorischen Phrase bezeichnen.

The changes (or fluctuations) of tone height are obviously of a continuous nature. The possiblity of phrase segmentation into minimal functional intonation units — called here intonational segments — depends on the syllable structure (MSB 4, p. 402):

> Die Gesamtheit des Tonhöhenverlaufs innerhalb einer beliebigen phonetischen Silbe, die zumindest ein stimmhaftes phonetisches Segment enthält, wollen wir als das intonatorische Segment bezeichnen.

Intonational segments are ordered by the relation of succession in time. Additionally, all these relations can be classified in a natural way by means of the relation here termed "the relation of isophoneticity". I shall omit here the definition of the relation which can be found in MSB 4, pp. 403–404 and restrict myself to enumerating below the seven abstraction classes which correspond to the sets of intonational segments actually found in the Polish language:

1. level
2. rising
3. falling
4. weak falling-rising
5. strong falling-rising
6. weak rising-falling
7. strong rising-falling.

The author treats the notions of a stressed syllable and of a rhythmic pattern of an utterance (Sprechtakt) as her primitive terms. She does so for the following two reasons:

— she considers all the theoretical solutions concerning the two notions arrived at so far (as they are presented in the literature of the subject) to be wholly unsatisfactory; and

— the properties of stressed syllables and rhythmic patterns which she needs to define her tonal units are practically independent of any formal definitions of the two notions she could have eventually adopted.

The stress-intonation structure of a rhythmic pattern is determined by referring to:

— the number of intonational segments of which a given rhythmic pattern is composed,

— the membership of an individual segment within a given class of "the isophoneticity relations",

— the respective positions of the mutually interdependent intonational segments within a given rhythmic pattern,

— the position of the stressed intonational segments within rhythmic patterns.

The mapping, however, of the stress-intonation structure upon rhythmic patterns does not consist in explicitly defining the former notion but in establishing a classification of the whole set of rhythmic patterns into sub-classes subsuming patterns of an identical stress-intonation structure (to do that, the author made use of the equivalence relation whose definition can be found in: MSB 4, pp. 406-407).

In this work Maria Steffen-Batóg introduces a method of assigning unequivocal graphic representations to any stress-intonation structure (the unequivocalness consists simply in that all the rhythmic patterns of the same stress-intonation structure are assigned identical representations).

The next two terms defined in the paper are: the relation of homotonality and the notion of a tonal unit (MSB 4, pp. 409–411):

> Wir wollen die Melodieverläufe innerhalb zweier beliebiger Sprechtakte T_1 und T_2 prüfen. Es ist ganz selbstverständlich, daß wenn T_1 dieselbe akzent-melodische Struktur wie T_2 besitzt, zwischen ihren Melodieverläufen eine engumschriebene Beziehung, nämlich die Beziehung einer großen Ähnlichkeit besteht. Diese Beziehung wollen wir Homotonalität nennen. Wir werden also sagen, daß der Melodieverlauf innerhalb des Sprechtaktes T_1 mit dem Melodieverlauf innerhalb des Sprechtaktes T_2 homotonal ist, wenn und nur wenn T_1 dieselbe akzent-melodische Struktur besitzt wie T_2.
>
> Es sei V der Tonhöhenverlauf innerhalb eines konkreten Sprechtaktes T_1. Wir wollen nun eine Tonhöhenverlaufsklasse X bilden, zu der wir nur diejenigen Melodieverläufe innerhalb der Sprechtakte zählen werden, die mit

> V homotonal sind. Die so gebildete Klasse X wollen wir eine dem Tonhöhenverlauf V entsprechende Tonaleinheit nennen; den Tonhöhenverlauf V wollen wir hingegen eine Realisierung der Tonaleinheit X nennen.
>
> Eine allgemeine Definition des nichtrelativen Begriffs der Tonaleinheit würde folgendermaßen lauten:
>
> Eine Klasse X ist eine Tonaleinheit dann und nur dann, wenn es einen solchen Sprechtakt gibt, daß X eine dem Melodieverlauf innerhalb dieses Sprechtaktes entsprechende Tonaleinheit ist.

One can see from the above definition that each tonal unit is a set of homotonal melodic sequences (Melodieverläufe). In the language material which the author had analysed — and which consisted of 10 000 rhythmic patterns (Sprechtaktes) — 544 distinct tonal units were found of various stress-intonation structures.

The notion of a stress-intonation structure for intonational phrases is defined in a way analogous to the definition of the same structure for phonetic phrases (MSB 4, pp. 411-412).

Now we come to the notion which is fundamental for the dissertation, namely that of the intoneme. Its definition is based on distributional relations (MSB 4, p. 416):

> Eine Tonaleinheit X_1 ist durch die Tonaleinheit X_2 in der akzent-melodischen Struktur S einer Phrase in der Stellung p austauschbar dann und nur dann, wenn der Austausch der Tonaleinheit X_1 durch die Tonaleinheit X_2 in der Struktur S in der Stellung p S in eine neue Struktur irgendeiner Phrase umbildet.
>
> Eine Tonaleinheit X_1 ist der Tonaleinheit X_2 funktionell gleichwertig dann und nur dann, wenn die Einheit X_1 durch die Einheit X_2 austauschbar ist und die Einheit X_2 durch die Einheit X_1 austauschbar ist in jeder einer Phrase entsprechenden akzent-melodischen Struktur S in jeder möglichen Stellung.
>
> Ist X eine beliebige Tonaleinheit, so wollen wir die Klasse aller und nur jener Tonaleinheiten, die der Einheit X gleichwertig sind, das dieser Einheit entsprechende Intonem nennen, die Tonaleinheit X wollen wir dagegen als einen Repräsentanten dieses Intonems bezeichnen. ...
>
> I ist ein Intonem dann und nur dann, wenn es eine derartige Tonaleinheit X gibt, daß I eine Klasse der Tonaleinheiten ist, die das Tonaleinheit X entsprechende Intonem bilden.

The author empirically establishes that there are 26 distinct intonemes in the Polish language. The simplest way to describe those intonemes is by determining two general classifications of all the possible intonemes:

I. Considering the melodic sequences (Melodieverläufe) which may be found within the melodic nucleus (Kernmelodie), one obtains the first general classification of all the intonemes into seven classes (these classes correspond exactly to the seven classes of intonational segments which were listed above) — see: MSB 4, p. 419:

> Durch die Kernmelodie eines Melodieverlaufs innerhalb eines gegebenen Sprechtaktes bezeichnen wir den terminalen, mit dem Anfang der akzentuierten Silbe beginnenden Abschnitt dieses Verlaufs.

II. Taking into consideration the relation between the maximum and minimum values of the melodic sequence (Melodieverlauf) inside the melodic nucleus (Kernmelodie) on the one hand, and the same value calculated for the intonational segment which immediately precedes the nucleus on the other, then one arrives at the general intoneme classification of the second type (MSB 4, p. 426):

> Neben der Teilung der Gesamtheit der Intoneme nach dem Typ des Melodieverlaufs innerhalb der Kernmelodie wenden wir noch eine andere Teilung an, die sich auf die Beziehung zwischen den maximalen und minimalen Werten des Melodieverlaufs innerhalb der Kernmelodie und des ihr vorangehenden nicht akzentuierten Melodieabschnitts stützt. Aufgrund dieses Kriteriums werden die folgenden Intonemartem unterschieden:
>
> hoch tief
> voll neutral.

By crossing the two classifications, one arrives at 28 possible types of intonemes. For purely theoretical reasons no intoneme of the type full — level can exist. The theoretically possible intoneme of the type high — weak falling-rising was not found in the analyzed speech material.

The remaining 26 intonemes form the intonemic system of the Polish language. Maria Steffen-Batóg tries then to characterize the set of intonemes establishing a carefully chosen inventory of distinctive features which differentiate them. She arrived at her set of distinctive features by defining the six binary parameters which resulted from answering the following six yes/no questions (MSB 4, p. 428):

> 1. Ändert der Tonhöhenverlauf im Bereich der Kernmelodien aller dieses Intonem repräsentierenden Realisationen die Richtung?
>
> 2. Kann die Dauer der Kernmelodie jeder Realisation dieses Intonems in zwei Abstände so eingeteilt werden, daß die Tonhöhe im Bereich des ersten Abstands eine nicht-konstante und nicht-fallende Funktion der Zeit ist?
>
> 3. Ist der Anfangswert der Funktion, die den Tonhöhenverlauf im Bereich der ganzen Kernmelodien der Realisationen dieses Intonems beschreibt, höher als ihr Endwert?
>
> 4. Geht den Kernmelodien in den Melodieverläufen, die die Realisationen dieses Intonems bilden mindestens ein intonatorisches Segment voran?
>
> 5. Ist der Endwert der Funktion, die den Melodieverlauf im Bereich der nicht akzentuierten intonatorischen Segmente beschreibt, die den Kernmelodien der Realisationen dieses Intonems vorangehen, höher als der maximale Wert der Funktion, die den Tonhöhenverlauf innerhalb der Kernmelodien determiniert?
>
> 6. Ist der Endwert der Funktion, die den Melodieverlauf im Bereich der nicht akzentuierten, den Kernmelodien vorangehenden, intonatorischen Segmenten beschreibt, kleiner als der minimale Wert der Funktion, die den Tonhöhenverlauf innerhalb der Kernmelodien der Realisationen dieser Intonems determiniert?

Each Polish intoneme can be unequivocally assigned a sequence of yes/no answers to the above questions and thus differentiate it from the remaining 25 intonemes (questions 5 and 6 are irrelevant for all neutral intonemes). Being able to determine a complete list of intoneme differentiating features was considered by the author very important for practical reasons as well. She explains that in the manuscript of her Ph.D. dissertation (pages 162–166) where she also presents some examples of application of these distinctive features:

> Having established a complete inventory of the distinctive features for all Polish intonemes, we may easily formulate a set of formal criteria which would allow us to assign all tonal units to respective intonemes. They would also always let us determine unequivocally to which intoneme a given tonal unit belongs with no need of having recourse to a definition of its functional equivalence, but only on the basis of the phonetic shape of a given unit. Thus, for example, for the intoneme defined as full — falling a formal criterion could look like that:

A tonal unit X belongs to (is an element of) the falling — full intoneme if and only if each melodic sequence x which is the implementation of that tonal unit X has the following three properties:

(1) the tone height within the nucleus of the sequence x is — with respect to perception — a non-constant and non-increasing function of time;

(2) x begins with an unstressed intonational segment;

(3) with respect to perception, the final tone height within the intonational segment which immediately precedes the stressed segment is lower than the maximum height of tone and also higher than the minimum height of tone within the nucleus of the sequence x.

MSB 4 closes with a definition of the functional structure of a phrase and a suggestion concerning the method of representing such structures graphically. Generally, the notion of a functional structure of a phrase is to account for our intuitions as to the role intonation plays in the organization of information in utterances. In conclusion, I would like to state again that MSB 4 is a beautiful piece of research work.

At the end of this section, I would like to say a few words on the author's other papers dealing with the intonation system. Thus, MSB 6 analyses the influence that the intrinsic vowel pitch may have in Polish upon the differences in the realizations of intended intervals. At the same time, the author wanted to experimentally test whether the so called level theory (as worked out in Lehiste-Peterson 1961) could be used to adequately describe the Polish intonation system in terms of musical intervals. The study was based on a list of 74 logatomes, or meaningless sound sequences representing the VCV combinations in which the initial vowel was invariably /a/. In the following CV complex C was always a voiced phoneme combined with the following vowels so as to exhaust all the phonotactically permissible CV combinations of the Polish language. The 444 oscillograms made of the recordings of those logatomes (they were uttered by six male voices) showed that the maximum difference in the realizations of an intended interval was approximately two semitones and that the extent of the observed difference depended mainly on the qualitative differences of the "word"-final vowels. Besides, the results seem to be influenced by considerable interpersonal differences. The author concludes that the intonation system of the Polish language cannot be adequately described by means of the theoretical apparatus worked out within the level theory.

Then, in MSB 11 similar experimental methods were used to determine for a set of 13 voiced consonants the effects which the F_0 values in the neighbouring vowels and the manner and place of articulation of the examined consonants may have on their fundamental frequency values. The study was based on the oscillograms made of recordings of 13 nonsense words of the VCV structure which were read eight times by four persons; the intonation of each reading was to be different (three types of the intonation were preordained by the experimenter). On the basis of the oscillograms and statistical analysis of the results, the author arrived (among others) at the following conclusions:

- 1. The average value of F_0 for the consonants which appeared in the logatomic VCV structures analysed depends on the values of the same parameters as determined for the preceding and following vowels (additionally, it depends on an experimentally calculated value of a coefficient).
- 2. The set of consonants analysed in the paper included two groups of sounds of which the first comprised stops, fricatives and affricates, whereas the other consisted of nasals and /l/. In the latter group the drop of the F_0-value in relation to its value determined for the neighbouring vowels was smaller than in the case of the former group. The results did not confirm Hegedüs' hypothesis claiming that for fricatives the drop should be smaller than in the case of stops.

The Poznań school of acoustic phonetics has for a long now been famous for its research on the acoustic features which make it possible to identify voices of individual speakers. Such studies usually form part of a wider programme which encompasses such problems as for instance speech recognition (whether automatic or not), and speech synthesis. Possible applications of the results in this domain of research are many and varied — from neurology and telecommunication to forensic studies. They are, however, equally important in determining the adequacy of the linguistic description as such (as they let us, among other factors, distinguish between linguistically essential and marginal acoustic parameters). Maria Steffen-Batóg's article MSB 7, which she wrote with W. Jassem and H. Gruszka-Kościelak, examines the possibility of finding personal voice characteristics on the basis of an analysis of statistical distribution (in 50-millisecond segments) of short-term F_0-values [fundamental frequency of the larynx tone]. Her data consisted of a simple newspaper text taking approximately 1 minute to read. The text was read by six speakers at ordinary speed and recordings were made. Quasi-periodic fragments of the oscillograms made from the recordings were divided into 50-millisecond segments and average fundamental frequency was calculated for these segments. The statistical results of the study showed that speaker discrimination is possible if based on the analysis of certain values of central tendency and dispersion determined for the statistical distribution of short-term F_0-values (which can itself be profitably used for voice discrimination if calculated for the samples of between 10 and 50 seconds).

3.2 Stress

Maria Steffen-Batóg's first work on stress perception in Polish was MSB 5 (written together with W. Jassem and J. Morton). It was in a sense a continuation of some earlier studies by Jassem which attempted to establish the acoustic parameters, the variations of which would most adequately account for the phenomenon of stress in Polish. Having analysed such parameters as intensity, duration, pitch and vowel quality for stressed and unstressed syllables, Jassem put forward the hypothesis that what most consistently makes the stressed syllable in Polish differ from the neighbouring unstressed one is pitch. The hypothesis was confirmed in MSB 5. Synthetic speech and a panel of one hundred listeners were used for the purpose. It was found that an increase in duration or intensity should only be considered accessory features of the stressed syllable. Besides, the auditory evaluation of nonsense words (logatomes) showed that durational variations formed a stronger cue for stress perception than the variations in intensity levels (the two types of variations were contrasted with constant F_0 value).

MSB 21 is a conference paper in which Maria Steffen-Batóg presented the development of studies on the perception of stress in Polish. The author stressed the fact that most publications on the subject were studies based almost exclusively on their authors' linguistic competence or their own individual, accidental observations and impressions. She pointed to the urgent need for more extensive experimental studies on the Polish stress system free from the subjective judgments she had illustrated earlier. Then, she went on to present in the paper the results of an experiment analysing the influence of speech tempo on stress perception. Here are some of the conclusions arrived at by the author:

- 1. The faster is the speech tempo (of the utterances produced by a given voice), the lower is the number of the stressed syllables perceived in those utterances, though the decrease may vary depending on individual word forms.

- 2. The probability of recognizing initial syllables as stressed is higher in the case of fast speech tempo.

- 3. Among the factors which determine the percentage of correctly recognized stressed syllables within individual word-forms, the most important two are: the syntactic structure of an utterance and the position of sentence stress within the utterance.
- 4. Traditional descriptions of the Polish stress system which divide all word-forms in Polish into either atonic or orthotonic ones do not seem — in the author's opinion — to be consistent with the linguistic reality. She thinks that they should be replaced with a probabilistic model which would define stress structures of Polish in more rigorous terms of conditional probabilities.

Similarly, MSB 19 — a paper published in the same year — deals with the problems of stress perception. It also presents a description of an experiment the results of which indicate, among others, that in stress recognition — in addition to purely phonetic factors — other factors (the author points to language fluency) seem to play an important role too. I shall not go into any details here, and say only that the experiment attempted to find out which group of students will have less problems with recognizing stress in the German language. Advanced students of German Philology were compared with students of Polish Philology who had no knowledge of German. The author considers the results of her work important for the theory of foreign language teaching.

The five works which Maria Steffen-Batóg published in recent years (namely, MSB 23, 24, 25, 27 and MSB 28) and which deal with stress seem to form a relatively coherent whole. In MSB 27 she discussed some basic assumptions of Maria Dłuska's theory of stress groups and Witold Mańczak's theory of word groups. The most important part of the paper, however, deals with the problem of which elements of the stress structure of utterances in Polish are really perceptually relevant for the native speaker of Polish. The author asks the following four questions (MSB 27, p. 144):

> 1) Are stress groups perceived as distinct units of the stress structure (of the language) by native speakers of Polish, or are they not?
>
> 2) Do really perceptible physical characteristics of the utterance make it possible to identify — unequivocally and uniformly — the syllable which carries the main stress and to determine — in a similarly uniform and unequivocal manner — the boundaries between consecutive stress groups?
>
> 3) Is there any such ability — in the auditory perception of native speakers of Polish — that would account for and justify Dłuska's firm insistence that

the number of main stresses should be equal to the number of the clearly demarcated stress group boundaries which correspond to the main stresses?

4) Is the stress structure of Polish utterances (as determined by native speaker's auditory perception) dependent on the quality of the linguistic material analysed?

Omitting, as before, the description of her experiments, I would like to present below the author's conclusions (MSB 27, pp. 161–162):

1) Native speakers of Polish can differ considerably among themselves in their perception of the stress structure of utterances produced in their mother tongue.

2) Among the reasons underlying those differences one should point to the following two:

a) the fact that the degrees to which main stresses and stress group boundaries are brought into prominence may vary considerably, and

b) the fact that individual speakers differ radically with respect to the sensitivity to the acoustic stimuli which signal the occurrence of the two elements of the stress structure which were mentioned above.

3) Speech tempo is a factor which can strongly influence the speaker's perception of the stress structure. With the growth of speech tempo, one can typically observe a simultaneous decrease of:

a) the average number of main stresses and stress group boundaries perceived by the native speaker;

b) the sum total of subjects (listeners) who would agree in their assessment of the numbers of main stresses and stress group boundaries which results from a drop in the perceptual distinctness of those prosodic units;

c) the structure index which defines the ratio between the number of final stress group boundaries and the number of main stresses. The drop in the value of the index proves that the growth of speech tempo leads first of all to the obliteration of stress group boundaries.

4) As the index which was mentioned above is different for different varieties of spoken Polish it may be used as a parameter which defines the way in which the stress structure is organized within an utterance of a particular type.

In MSB 25 and 28 we find further confirmation of the conclusions quoted above. Additionally, the two papers made use of the results arrived at in MSB 23 and MSB 24 (the latter written together with K. Katulska). The two latter papers dealt with the relationship between the perceptual acoustic features of stressed syllables on the one hand, and the possibility of finding (or determining) which syllables are stressed and where stress group boundaries are set on the other. The tests used by the author showed that the perception of main stress varies a great deal with individual subjects (listeners). Besides, the results showed unmistakably that fewer stress group boundaries are perceived (or distinguished) than main stresses (the results seem thus to invalidate Dłuska's thesis which I mentioned earlier in this paper). It is therefore possible to advance a hypothesis that stress group boundaries are perceptually less distinct than main stresses. The author confirmed the hypothesis (using the t-test and Ferguson's test) by finding that the difference is statistically significant. The phenomenon itself could be explained by the fact that main stress in Polish is predictable (it plays the role of a word delimiter). The boundaries — on the other hand — between stress groups depend not only on the grammatical structure of an utterance, but also on such factors as lexical meanings, clarity or distinctness of speech, as well as on the personal idiosyncrasies of individual speakers.

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18. Wstępny algorytm konwersji polskich tekstów fonematycznych w ortograficzne (An introductory algorithm for the conversion of Polish phonemic texts into their ortographic counterparts). *Lingua Posnaniensis*, **XX**, 65–95. (Co-author: T. Batóg).

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