Mária Gósy

THE MANIFOLD FUNCTION OF SCHWA

INTRODUCTION

In the middle of the vowel space a neutral vowel can be found that is central in terms of tongue position (in to both dimensions). In other words, this [ə] vowel is produced with the vocal tract in its neutral configuration while, according to the definition, the lips are unrounded. The neutral vowel has got various names like obscure vowel, indeterminate vowel, reduced vowel, central vowel, medial tongue vowel, murmured vowel, unstressed syllable vowel, etc. Most frequently it is called 'schwa'. This word comes from a Hebrew word meaning 'nothingness'. The name *schwa* was first used in English in 1895 in Peter Giles' *A short Manual of Comparative Philology for Classical Students*. The symbol of the schwa, i. e. the inverted *e*, has been around in phonetics for much longer. This was used for the first time with the modern IPA value by the German linguist, Johann Andreas Schmeller in 1821. However, the name *schwa* was not used until Giles (MacMahon 2003).

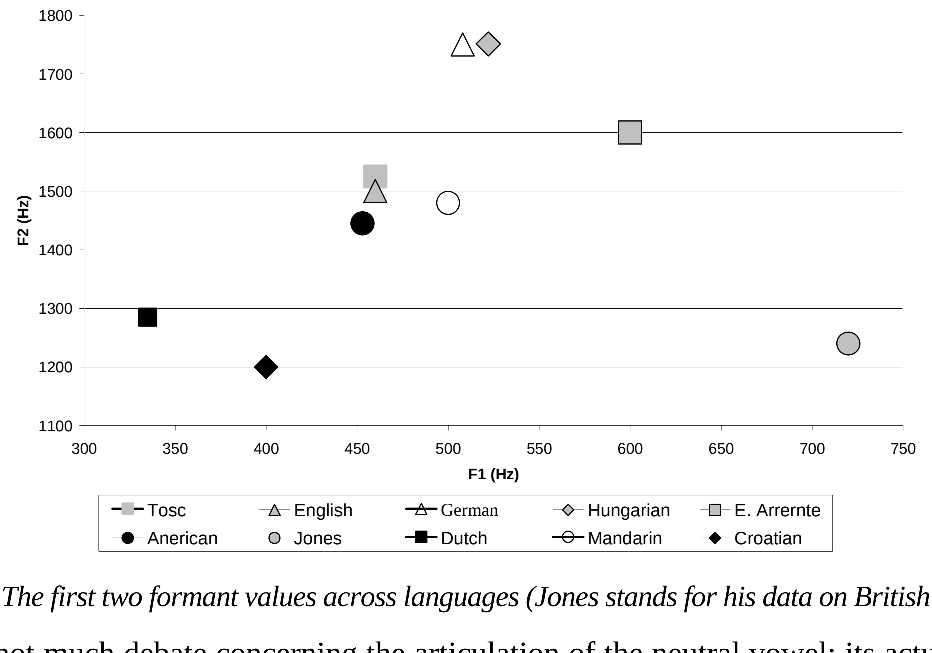

Figure 1: The first two formant values across languages (Jones stands for his data on British English)

There is not much debate concerning the articulation of the neutral vowel; its actual articulation configuration is more flexible than that of most other vowels. The variability of schwa ranges from extreme back to extreme front articulation and – according to its formant values in various languages – primarily the height of the tongue but also the horizontal movement of the tongue show enormous differences. *Figure 1* summarizes the F1/F2 space for some [ə] vowel in diverse languages.

The acoustic data of the neutral vowel across languages show relatively great differences in its frequency structure, which raises the following questions. Does a "neutral" articulation of such vowels exist? Or, is neutral articulation heavily language-dependent? 'Neutral configuration' can be explained theoretically as it is but the actual articulation and its acoustic consequences are dependent on the vowel space of a language which determines people's perception.

Its exact articulation is not the only debated point about the neutral vowel. If we try to define its function we might conclude that this vowel has got more functions in speech than any other signal used in verbal communication. In the literature, there are many functions of this vowel listed in various languages; however, none of these surveys seem to be complete. Let us look at all possible functions and their actual realizations of the neutral vowel focusing on Hungarian in further analysis.

FUNCTIONS OF SCHWA

Analyzing the vowel inventory of languages it is evident that [ə] can represent a *phoneme* and also an *allophone* (Jones 1966; Koopmans-van Beinum 1994; Laver 1994; Barry 1995; Ladefoged/Maddieson 1996; Hirschfeld/Wallraff 2002; Granser/Moosmüller 2003). 42 % of the languages included in the IPA Handbook (1999) uses the neutral vowel as a phoneme like Amharic, Sindhi, Slovene, etc. The vowel inventory of Croatian, Catalan, Hebrew, Irish and some other languages contains schwa in the function of an allophone. The neutral [ə] is a phoneme and also an allophone in German, with a rate of occurrence of about 30 % of all vowels. The reduced vowel appears in English spontaneous speech in 22.9 % while in French in 7.6 % of all vowels (Onishi 1981). Contrary to allophonic schwa, the variability of schwa as a phoneme is a lot more independent of the consonantal environment (Ladefoged/Maddieson 1996). Hebrew shows an extraordinary application of the schwa when it signals the absence of a vowel. Schwa epenthesis is, for example, an abstract phonological process in Dutch involving insertion of some unit (Warner et al. 2002). In many languages – like Spanish or Hungarian – the neutral vowel is neither a vowel phoneme, nor an allophone; however, it occurs *replacing various vowels* in spontaneous speech as a result of careless articulation or fast speech tempo (Hargmenies/Poch-Olivé 1992). The schwa vowel can be a result of *coarticulation* or, in other words, of physiological necessity with three types of context-dependent occurrences: (i) as a result of co-articulation with specific consonants within and across syllables (Hungarian examples: *gnú* 'gnu' *g*[ə]*nú* or *teknő* 'trough' *tek*[ə]*nő* (cf. *Figure 2*); (ii) as a consequence of word final position after specific consonants, like [b, d, g, m, n]# → *adag*[ə], 'portion' (cf. *Figure 3*), and (iii) as a part of the initial [r] articulation at the very beginning of words, like #*róka* → [ə]*róka* 'fox' (cf. *Figure 4*). In other words: schwa vowels have the function to serve some segmental and rhythmic needs connected with ease of articulation.

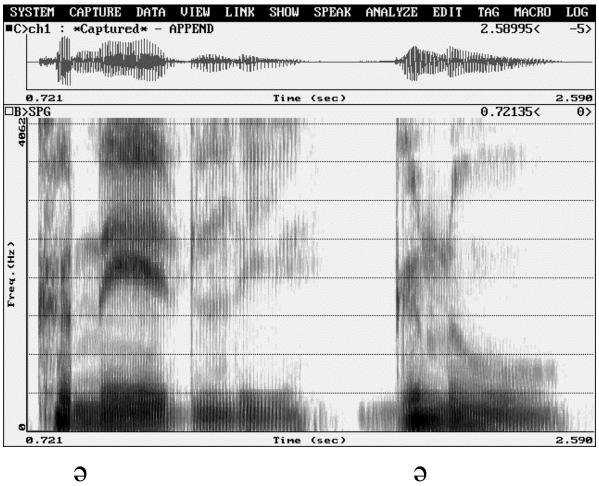

Figure 2: The Hungarian words knédli *'knödel: a sort of dumpling' and* gnú *'gnu' with schwa occurring between the members of the consonant clusters*

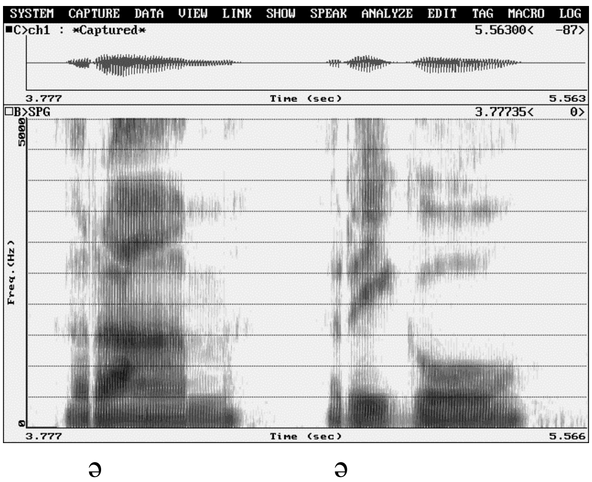

Figure 3: The neutral vowel in the initial [r] consonant in rám *'on me' and* rigó *'thrush' words*

There are various points in speech where the speaker intends to emphasize something for diverse reasons (in the case of logical or emotional stress or semantically ambiguous sound-sequences, etc.). The neutral vowel has got an important function in these cases signaling word boundaries though its occurrence in these places is also a consequence of physiological need. Example: *arab lány* 'Arab girl' vs. *a rab lány* 'the imprisoned girl' or *'halálok* 'deaths (pl.)' vs. *halál'ok* 'death reason'.

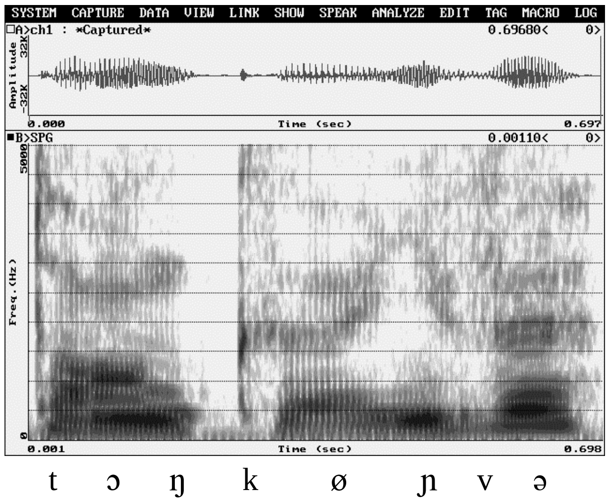

Figure 4: The word tankönyv *('school text book') with the [ə] vowel after the final consonant*

Schwa appears as a *proto-vowel* during the first months of life in the first phases of babbling (cf. *Figure 5*). The baby's vocal folds are working while his/her tongue and lips are in a more or less neutral position resulting in a vowel-like sound that reminds the adult listeners of a vowel-like sound and is identified by them as a schwa.

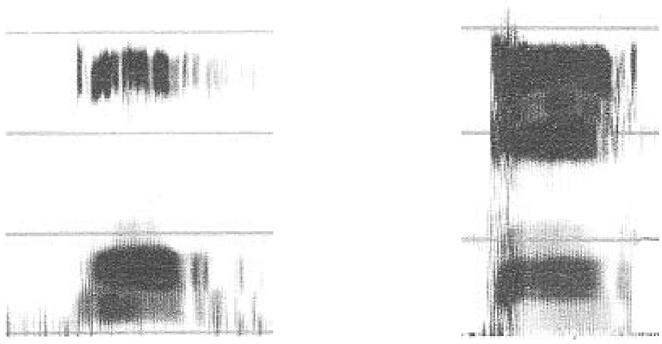

Figure 5: The neutral vowel (left) and the [ø] vowel (right) in babbling

During spontaneous speech the speaker might come across speech *planning* or *word finding problems*. Hesitation represents a trouble spot and it can also signal the forthcoming difficulty. These situations are verbally marked by a schwa-like vowel produced with diverse durations. Hesitation manifested by schwa is very much language-specific in Hungarian fluent speech.

The different functions of schwa are supposed to appear at various levels of the speech production process from the level of concepts up to actual articulation (*Figure 6*). Three functions – signaling boundaries, being a phoneme or an allophone – are supposed to be connected with two levels, i. e. with both grammatical and phonological encoding. Coarticulation and replacement of other vowels of a language are connected both with phonological encoding and articulation planning. Schwas in word final positions are supposed to be in contact with articulation planning while the schwa occurring as part of the initial trill articulation is purely an articulatory consequence. In the latter case, the vocal folds vibrate earlier than the consonant-specific vibration would take place in the mouth cavity while the articulatory organs are in a roughly neutral position waiting for the possibility to start the mechanical vibration of the tongue tip.

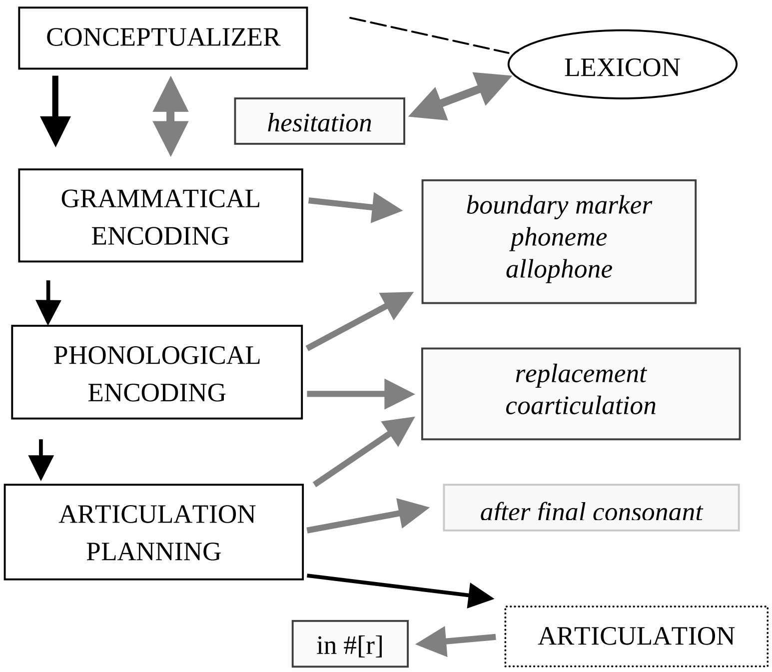

Figure 6: The hypothesized appearance of the neutral vowel with diverse functions in the speech production model

Though there is no debate about the existence of all these functions described above, the question arises here whether the articulation of the neutral vowel varies depending on its functions. To answer this question a series of experiments has been carried out with all listed functions of this vowel in Hungarian.

SUBJECTS, METHOD, MATERIAL

Altogether 10 young females (ages between 21 and 30) and a male baby (between the ages of 0;1 and 0;10) took part in the experiments. The speech material consisted of 120 words in isolation, 25-minute spontaneous speech, and 3-hour babbling. The isolated words contained the neutral vowels in various functions like physiological needs including words with initial [r], and in the role of boundary marker. Acoustic measurements concerned the duration and the first three formant values of the neutral vowel in various occurrences using the CSL 4300B system. The statistical evaluation of the data (based on the ANOVA procedure) was carried out with the help of a SPSS for Windows 8.0 software package. In all cases confidence level was set at the conventional 95 %.

RESULTS

The spectrum envelope of the neutral vowel arises from its oral tract shape. The sound originates from the vibrating of the vocal folds and is inserted into the tube (articulation cavities) and has a spectrum envelope that slopes downward in intensity from low to high frequencies. In the modeling tube some frequencies are emphasized more than others. The first peak in this model is at 500 Hz, the second at 1500 Hz and the third one is at 2500 Hz (Pickett 1980). In natural vowel production the spectrum of the sound is very similar to the modeled sound, but the peaks appear at lower frequencies, at 475, 1450 and 2375 Hz. The resonance pattern results in a slightly downward shift in this case. Another hypothetical model focusing on correspondence between phonological feature and formant values shows the following data for schwa: F1 = 370 Hz, F2 = 1630 Hz, F3 = 2600 Hz (ten Bosch 1991: 45). There are two main points that are emphasized in the literature about the acoustic structure of schwa. (i) The variability of the schwa vowel is defined along the second formant. (ii) Mean values of phonemic schwa show slightly peripheral values for F2 (e. g. about 1600 Hz for Eastern Arrernte (spoken in Australia) or 1220 Hz for Beijing Mandarin, cf. Granser/Moosmüller 2003).

In Hungarian the schwa vowel is neither a phoneme nor an allophone but it appears in spontaneous speech replacing various vowels both in stressed and unstressed positions. To start the analysis it was crucial to make sure that the supposed two vowel qualities, [ø] and schwa really exist in Hungarian independently of the obvious similarity of the way they sound. Spontaneous speech was analyzed in this respect and comparisons were made between the Hungarian palatal labial mid vowel and the schwa (in various occurrences). The first and third formant frequencies of the two vowels are not significantly different. The values of the first formants, however, are significantly different (t(-2,072), $p < 0.042$). *Table 1* shows the measured data.

Vowels	F1 (Hz)		F2 (Hz)	
	mean	std. dev.	mean	std. dev.
[ə]	549.07	109.52	1787.5	149.31
[ø]	460.12	75.1	1605.94	185.91

Table 1: The formant values of [ə] and [ø] vowels in Hungarian

The occurrences of the replacements (their frequency and the actual vowels that are replaced) are dependent on the actual articulation, i. e. on the speaker's speech tempo and pronunciation characteristics (sometimes it is about 40 % of all possibilities). A similar ratio was found with Dutch speech (van Bergem 1995). The neutral vowels frequently appear in unstressed position while 25.02 % of all schwa representations replace stressed vowels (Gósy 2004). *Table 2* summarizes the acoustic data of these vowels. Perceptual tests confirmed the existence of the neutral vowels in spontaneous speech; listeners were able to detect the schwa vowels in the experimental material (Gósy 1997). No significant differences could be confirmed between the durations of the original and the schwa vowels.

Vowel	Mean durations and formant frequencies					
	original vowel			schwa vowel		
	duration (ms)	F1 (Hz)	F2 (Hz)	duration (ms)	F1 (Hz)	F2 (Hz)
o	30-90	340-510	720-1100	40-85	310-500	1075-1600
ɔ	50-210	480-600	960-1230	25-155	390-540	1160-1500
aː	80-155	600-760	1330-1510	50-124	395-620	1415-1770
E	47-200	480-585	1460-1835	28-130	370-570	1060-1785

Table 2: Acoustic data of four Hungarian vowels and of their replacements by neutral vowels in spontaneous speech

The question is whether the supposed articulation differences in schwa production in diverse functions can be verified by different temporal patterns and diverse formant values. Temporal analysis of the neutral vowels shows significant differences between hesitations and other physiologically explained occurrences (paired sample *t* test: t(-3,708), $p < 0.003$). The average duration value of the schwa in hesitation is 675.88 ms (std. dev.: 743.52) while the mean value in word boundary signaling function is 80.88 (std. dev.: 20.46), in coarticulation it is 38.74 ms (std. dev.: 9.3), in absolute word final position it is 71.92 (std. dev.: 25.15) while as part of [r] consonant in initial position it is 52.76 (std. dev.: 15.8). No significant difference was found between the word boundary signal function and the word final position. The duration of the neutral vowel shows extremely great differences between those occurring in the above mentioned functions and those replacing other vowels (cf. paired samples t-test: t(-3,470), $p < 0.001$).

The analysis of the acoustic structure of the Hungarian neutral vowels revealed that there are significant differences depending on function. However, there are not as many types of acoustic structure of schwa as many functions they have, cf. *Figure 7*. The mean value of the first formant in coarticulation function is 433.7 Hz (std. dev.: 44.285) while the mean of the other neutral vowels' F1 is 565.21 Hz (std. dev.: 69.986).

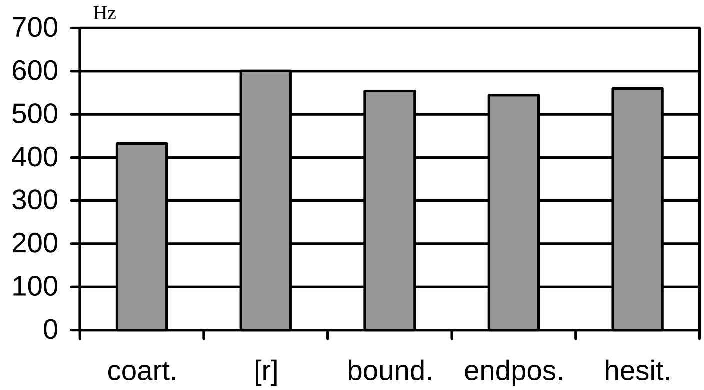

Figure 7: The mean values of the first formants of Hungarian schwa in various functions

Figure 8 demonstrates the mean values of the second formants of the schwa in various functions. The mean value of the schwa in coarticulation is 1751.75 Hz (std. dev.: 138.3), in word final position: 1748.72 Hz (std. dev.: 101.7), in boundary marker function: 1724.6 Hz (std. dev.: 183.83), as part of [r] 1786.4 Hz (std. dev.: 176.5) and in hesitation 1951.63 Hz (std. dev.: 118.15). These values appear in a wider frequency space, and the differences are significant between more cases than it was with the first formant frequency values. There are only three cases where the formant values are not significantly different: between [r] and the schwa appearing in word final position, or as boundary marker, as well as between boundary marker and word final position.

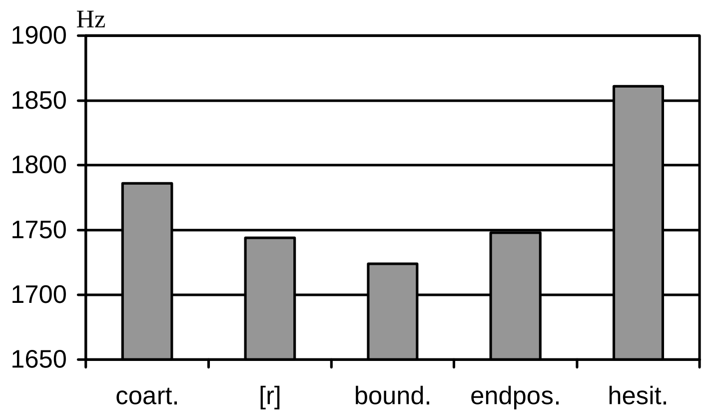

Figure 8: The mean values of the second formants of Hungarian schwa in various functions

If we take both formants (F1 and F2) into consideration it turns out that there are significant differences only in three cases which are coarticulation vs. hesitation, final position and boundary marker. This means that speakers unconsciously differentiate various neutral vowels when articulating them. It was expected that schwa vowels appearing in hesitations and in boundary marker position would show a different articulation configuration. It was not expected, however, that schwa in word final position would also show different patterns. The third formants do not show significant differences in the analyzed material, these values are the following: mean value in [r] 2859.57 Hz (std. dev.: 246.85), in boundary marker function 3005.66 Hz (std. dev.: 121.24), in coarticulation 2887.04 Hz (std. dev.: 342.06), in word final position 2981.28 Hz (std. dev.: 265.69) and in hesitation 2884.9 Hz (std. dev.: 147.28).

It is assumed that the neutral vowels in coarticulation functions might be different from those replacing vowels and appearing as hesitations in spontaneous speech. Statistical measurements confirmed this assumption. The first and third formants did not show great differences among the schwa vowels, but the second formants significantly differed ($F(2, 72) = 23{,}471$; $p < 0{,}0001$). The third formants of those neutral vowels that replace other vowel qualities occur at higher frequencies (according to the Kruskal Wallis Test it is close to a significant difference, $p < 0.055$). Similar results were found for example with the Mandarin schwa vowels that were analyzed in three different contexts: in syllable final position, in a sound combination with an alveolar nasal consonant ([n]), and in a position followed by a velar nasal consonant ([ŋ]). Averaged formant frequencies show that there are no differences in the first formant frequency values, however, remarkable differences were found with the second formant values (Sproat 1998).

Eighty babbled vowels that were identified either neutral or [ø] vowels were analyzed according to their first three formants. *Table 3* shows the values.

Identified vowels in babbling	F1 (Hz)		F2 (Hz)		F3 (Hz)	
	mean	std. dev.	mean	std. dev.	mean	std. dev.
ø	545.5	59.9	1985	273.9	3207.1	292.1
ə	502	47.85	2027	221.6	3021.4	242.3

Table 3: Formant frequencies of babbled vowels

The first formants of the babbled neutral vowel and the [ø] vowel show significant differences ($t(-2{,}409)$, $p < 0.026$) while there were no such differences in the case of the other two formants. This means that the babbling child during the first nine months of its life is able to differentiate these vowels by means of articulation gestures. It can be concluded that the baby uses the tongue height quasi-consciously to articulate diverse vowels since F1 refers to the motion of the tongue vertically in the mouth cavity. What is interesting here is that in adulthood the [ø] and the neutral vowels differ primarily in the F2 values that refer to the tongue movement horizontally in the mouth cavity. The F1 and F1 frequencies are plotted in *Figure 9* which shows considerable differences among the neutral vowels occurring in diverse functions.

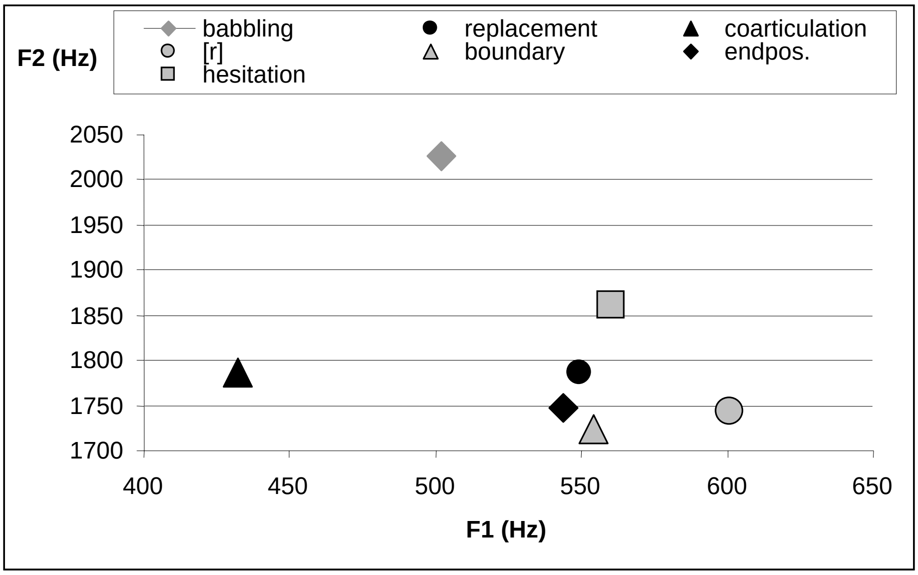

Figure 9: The F1/F2 space of the Hungarian neutral vowels in various functions

The question that arises here is whether the Hungarian schwa could be characterized by different articulation configurations depending on its function. Considering the first formants, Hungarian schwa is an unrounded mid vowel but it is palatal rather than central according to its actual values. However, if we look at the vowel space of the schwa, it is clear that it occurs somewhere in the centre of all the other Hungarian vowels approaching very much the formant space of the [ø] vowel.

CONCLUSIONS

The vowel [ə] is used from the very first weeks of life and is used even by practised speakers all the time. This is a mid-central, multifunctional speech sound that exists across languages. The articulation configuration of schwa is theoretically "neutral" but according to its frequency structure it varies across languages and also within a language depending on its actual function. The neutral vowel seems to be rather a perceptual sensation than a stable vowel with a relatively unchangeable acoustic structure. In the Albanian Tosc language a tendency is reported for schwa to be replaced by a back vowel (Granser/Moosmüller 2003). Measurements concerning Dutch schwa vowels confirm their relatively stable mid-central patterns in relation to other vowels of the language (van Bergem 1995). In Hungarian, schwa exists both in its canonical form and also a tendency can be witnessed which is a shift toward a slightly palatal articulation. Schwa is used in various functions across languages and within a language like a phoneme, an allophone, a specific sound for physiological needs of speech, signaling possibility in case of emphasis, searching in the mental lexicon or expression trouble. What is more interesting about schwa is that speakers of many languages decode it in the same or a very similar way independently of the actual knowledge of the language. So, schwa is not only the most "central" but also the most "international" vowel in verbal communication.

Kempelen wrote in his book more than 200 years ago that the human ear can be "deceived" since it hears what it wants to hear (i. e. perceive). The vowels of his speaking machine do not differ enormously from each other, however, listeners are able to hear different sounds in the words because they know what they intend to hear. The neutral vowel is a wonderful example of how the human decoding mechanism works: primarily by means of the objective parameters of the sounds but eventually by activating the supposed forms with the necessary meanings.

LITERATURE

Barry, W.J. 1995 Schwa vs. Schwa+/r/ in German, *Phonetica* 52: 228–235.

Bergem, D. van 1995 Perceptual and acoustic aspects of lexical vowel reduction, a sound change in progress, *Speech Communication* 16: 329–358.

Bosch, L.F.M. ten 1991 *On the structure of vowel systems. Aspects of an extended vowel model using effort and contrast*, Doctoral dissertation, University of Amsterdam.

Gósy, M. 1997 A magánhangzók minőségváltozásai a spontán beszédben, *Magyar Nyelvőr* 121: 45–56.

2004 *Fonetika, a beszéd tudománya*, Budapest.

Granser, Th./Moosmüller, S. 2003 Phonemic schwa – a challenge for Natural Phonology? The case of Albanian, in: Dziubalska-Kolaczyk, K./Weckwerth, J. (eds.) *Future Challenges for Natural Linguistics*, München: 165–178.

Handbook of the IPA 1999 Cambridge.

Harmegnies, B./Poch-Olivé, D.
1992 A study of style-induced vowel variability: Laboratory versus spontaneous speech in Spanish, *Speech Communication* 11: 429–437.

Hirschfeld, U./Wallraff, U. 2002 Untersuchungen zum Schwa im deutschen, in: Braun, A./Masthoff, H.R. (eds.) *Phonetics and its Applications*, Stuttgart: 493–505.

Jones, D. 1966 *The Pronunciation of English*, Cambridge.

Koopmans-van Beinum, F.J. 1994 What's in a schwa? Durational and spectral analysis of natural continuous speech and diphones in Dutch, *Phonetica* 51: 68–80.

Ladefoged, P./Maddieson, I. 1996 *The Sounds of the World's Languages*, Oxford/Cambridge, MA.

Laver, J. 1994 *Principles of Phonetics*, Cambridge, MA.

MacMahon, M.K.C. 2003 Schwa, *The Phonetician* 87: 8.

Onishi, M. (ed.) 1981 *A Grand Dictionary of Phonetics*, Tokio.

Pickett, J. M. 1980 *The Sounds of Speech Communication*, Baltimore, MD.

Sproat, R. (ed.) 1998 *Multilingual Text-to-Speech Synthesis: The Bell Labs Approach*, Dordrecht: 209–212.

Warner, N.L./Jongman, A./Cutler, A./Mücke, D. 2002 The phonological status of Dutch epenthetic schwa, *Phonology* 18: 387–420.

Mária Gósy
Phonetics Department, Research Institute for Linguistics, Budapest
gosy@nytud.hu