AN IPA VOWEL DIAGRAM APPROACH TO ANALYSING L1 EFFECTS ON VOWEL PRODUCTION AND PERCEPTION

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ABSTRACT

This paper examines the influence of the first language on the accuracy with which trained phoneticians judge isolated monophthongs taken from the phoneme systems of two different languages. The main finding of this study was that the speaker's as well as listener's L1 background have a significant influence on judgements which were made by means of the IPA vowel diagram.

This paper consists of 6 sections. In section (1) we will recall the basic principles of the IPA vowel diagram focusing on its layout, proportions, and primary cardinal vowels. In section (2) we will refer to the tradition of using the cardinal vowel system in phonetic studies, particularly in order to plot a vowel sound at a certain point within the space of the IPA vowel diagram. In section (3) we will suggest how the influence of the L1 on articulation and perception of vowels of an unknown language can be investigated with the help of the IPA vowel diagram. The methods which we used during the preparation of recordings and perception experiment, as well as subjects who took part in them, will be described in section (4) and a presentation of the main results will follow in section (5). Finally, we will discuss the results with respect to the three basic dimensions of the vowel sounds: height, backness and rounding.

1. IPA VOWEL DIAGRAM AND CARDINAL VOWELS

The IPA vowel diagram represents an abstract vowel space, which in its layout and proportions is derived from the one which had been used in the cardinal vowel system of Daniel Jones (e.g. Jones 1962 [1]). It has parallel top and bottom (hence a trapezium), right angles at top and bottom back and ratio 2:3:4 (base:back:top). This is the most simplified version of the figure developed by Jones through a number of stages, in which articulatory accuracy was progressively sacrificed for practical convenience in drawing the diagram (Ashby 1989 [2]). Layout and proportions of the vowel diagram are set in the IPA Handbook in accordance with the Kiel convention of 1989 [3].

The vowels are plotted on the diagram with reference to certain fixed points. Daniel Jones proposed a series of 8 (primary) cardinal vowels, spaced around the outside of the possible vowel area and designed to act as fixed reference points for phoneticians (Ladefoged 1993 [4], p. 219). The space within the diagram represents a continuum of possible vowel qualities which have to be identified by their relationships to the cardinal vowels. According to Daniel Jones a scale of these 8 cardinal vowels forms a convenient basis for describing the vowels of any language (Jones & Ward 1969 [5]).

Therefore any vowel pair of different qualities can be described as occupying different positions within the space of the diagram and can be identified by their relationships to the cardinal vowels (Lisker 1989 [6], p. 24).

2. USE OF THE IPA VOWEL DIAGRAM IN PHONETIC STUDIES

The cardinal vowel system has been extensively used by phoneticians in the description of a wide variety of languages (Ladefoged 1993 [4], p. 220). The description of vowel qualities with the help of the vowel diagram requires a phonetician to be able to position them as certain points on the diagram. The three basic dimensions, height, backness and rounding, together with the values of cardinal vowels are involved in making a decision on the position of the vowel quality within the space of the diagram.

Obviously, the values of the cardinal vowels must be known to both the phoneticians originally plotting the vowels and to the phoneticians who are going to interpret the descriptions. Daniel Jones's idea was that the values of cardinal vowels cannot be learnt by written descriptions; they should be learnt by oral instruction from a teacher who knows them (Jones 1962 [1], p. 34). Consequently, a phonetician has to be capable of distinguishing many more vowel qualities than there are in his own language and of judging the degree of their similarity. His doing so indicates that his L1 vowels are like known places on a map, and that he is making a phonetic judgement in stating the distance between one of his own vowels and a vowel pronounced by another speaker (Ladefoged 1967 [7], p. 55).

In this way the question as to what phoneticians should be aware of when they describe a vowel sound by plotting it at a certain point on the vowel diagram seems to be answered as follows: one could discriminate and plot a vowel sound correctly, if (i) the three basic dimensions of the vowel sounds, (ii) the values of cardinal vowels, and (iii) the layout and proportions of the IPA vowel diagram are well known and taken into consideration in making a final decision on the position of the vowel in the diagram.

3. ARTICULATION AND PERCEPTION OF VOWEL SOUNDS ON THE IPA VOWEL DIAGRAM

If we agree upon an assumption that phonetically trained subjects have knowledge of and experience with the three basic dimensions of vowel sounds and are aware of the values of the cardinal vowels on the IPA vowel diagram, then we should expect them to be able to produce almost any vowel sound plotted as a certain point within the space of the diagram. At least this can be assumed to be the case for the L1 vowels of the subject, as he is naturally well-trained in them.

In order to evaluate this hypothesis we could record a sequence of prototypical vowels taken from the phoneme systems of two different languages which have been elicited through specification of a number of anonymous points on the IPA vowel diagram. We would then present them for auditory judgement to a panel of equally qualified subjects. The recorded vowels would be judged according to their phonetic qualities and plotted back on the vowel diagram, which shows only the cardinal vowel symbols for orientation. Consequently, it can be expected that the points obtained in such a way should almost exactly match the initial points of the vowel sounds on the diagram. If one of the subjects produced the above mentioned sequence of vowels and after that judged them, then we could investigate whether his own judgements show significantly smaller deviations from the intended vowel qualities than the judgements of other subjects.

Let us refer here to the fact that the proportions and layout of the IPA vowel diagram are a result of Daniel Jones's intention to achieve a practical convenience in drawing the diagram despite the articulatory inaccuracy of the devised figure. Therefore the IPA vowel diagram is an 'impressionistic' tool which does not have a well defined relationship to any one physical domain (Nolan 1988 [8]).

Furthermore, the problem of how and where to position a particular vowel sound on the IPA diagram was a matter of discussion during the meeting in Kiel in 1989. A necessity to explicitly determine the process underlying the decision of phoneticians to plot this or that point representing a particular vowel sound was expressed (Nolan 1988 [8]).

Thirteen years have past since the Kiel Convention of 1989 [3]; a new generation of phoneticians has been giving oral instructions to students on how to pronounce and perceive vowel sounds analytically, i.e. independently from their L1, and how to use the IPA vowel diagram in phonetic studies.

By means of a perception experiment whose methods and subjects will be described in the next section we have tried to gain a clear understanding of the difficulties which could result from using the IPA vowel diagram in phonetic studies as well as from oral instructions by a teacher who is a speaker of a particular language.

4. EXPERIMENTAL PROCEDURE

4.1. Subjects

A total of four female subjects took part in both recordings and perception experiment. Two of them were native speakers of German and two were native speakers of Russian. At the time of the recordings all subjects were on the scientific staff of departments of phonetics in Germany and Russia. All subjects had graduated from the departments they were working at. They were phonetically trained and had already gained some experience in teaching phonetics. All subjects were aged 25 to 35.

4.2. Stimuli

Fourteen of the 20 initial points were taken from the "Handbook of the IPA" [9]. They represented the prototypical positions of 14 vowel phonemes of German on the diagram (see the filled dots in fig. 1). The other six points represented the prototypical positions of the vowel phonemes of Russian (see the open dots in fig. 1). They were taken from the "Phonetics of modern Russian" used recently in phonetic classes in Russia (Bondarko 1988 [10]) since the phoneme system of Russian is not included in the "Handbook of the IPA". The subjects were unaware of the fact that the presented points corresponded to the positions of the vowel sounds of their own language as well as of a second language which they did not speak.

The sequence of points was randomized in a way that would prevent tuning of the subjects to the three basic dimensions of vowel sounds (height, backness, rounding).

4.3. Recordings

The recordings were carried out in sound treated rooms at the departments of phonetics in Germany and Russia. Each of the four subjects produced 20 vowel sounds corresponding to the initial prototypical positions on the IPA vowel diagram.

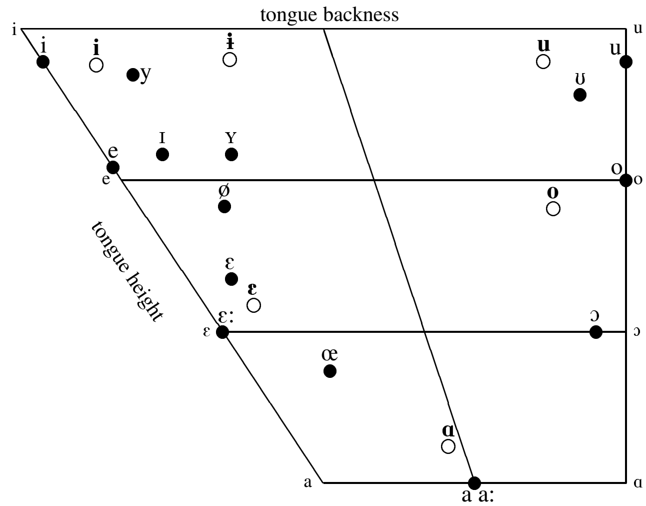

Fig. 1. Prototypical positions of German (filled dots) and Russian (open dots) monophthongal vowel phonemes put into the same vowel diagram.

For each vowel sound an anonymous point was presented on the otherwise empty IPA vowel diagram. Eight primary cardinal vowel symbols were spaced outside the diagram so that a better reference to the points could be achieved. For each sound we provided the subjects with written instruction about rounding or unrounding of the lips. The subjects were asked to produce the vowel sounds with equal length since the distinction between long and short vowels is a property of the phoneme system of a specific language. The objective was to receive vowel qualities which in the opinion of the subjects would be as long and as clearly articulated as would be required for quality transmission in an imaginary transcription class.

4.4. Perception test

As a result of the recordings we obtained 4 vowel realizations for each of the 20 initial points (see fig. 1). During the perception test a total of 80 vowel realizations was then phonetically judged by the same 4 subjects who participated as speakers in the recordings. The perception test took place in sound treated rooms at the department of phonetics in Germany and Russia a few days after the recordings. For each of the listeners there was a separate session.

The task of the listeners was to plot each of the 80 stimuli as a certain point on the IPA vowel diagram. For this reason we prepared 320 (80 stimuli per 4 listeners) empty diagrams with 8 primary cardinal vowel symbols spaced outside the trapezoid. Unlike the instructions during the recordings there was no information provided on lip rounding. The listeners were asked to assess it on their own by crossing the matching answer on a binary choice questionnaire submitted along with the diagrams.

The recorded stimuli were separated by short pauses and reproduced in random order. Randomization of the sequence aimed to avoid the listeners tuning into one of the three basic dimensions of vowel sounds as well as to one particular speaker. For each initial point we received 16 points plotted separately on 320 IPA vowel diagrams. Finally, we measured the coordinates of the 320 positions and converted them into machine-readable format.

5. RESULTS

For each of the four recorded vowel realizations of one initial prototypical position we received four points within the space of the

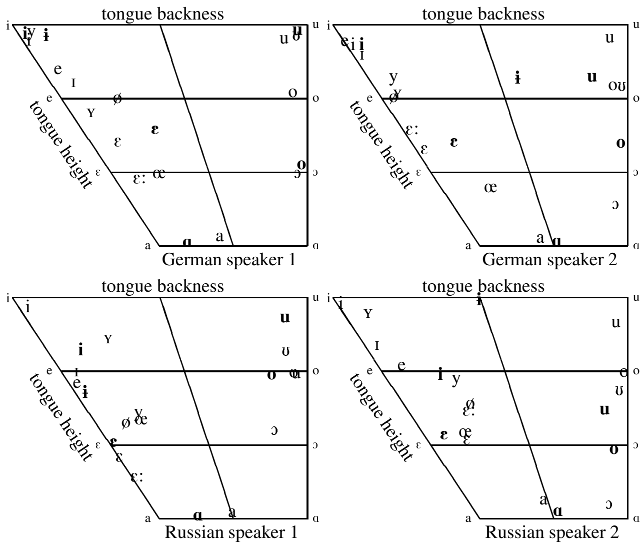

Fig. 2. Each cardinal vowel diagram shows judgements of 20 different vowel realizations. Each judgement is an average over the perception results of four phoneticians.

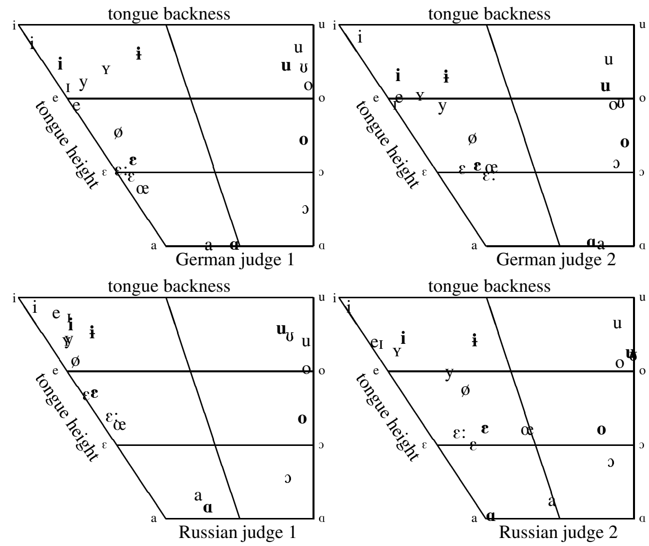

Fig. 3. Each cardinal vowel diagram shows 20 judgements each averaged over four vowel realizations per prototypical vowel position.

IPA diagram. In fig. 2 each cardinal vowel diagram shows judgements of 20 different vowel realizations. Each judgement is an average over the perception results of four phoneticians. If we compare the diagrams of fig. 2 with each other we can ascertain the inter-speaker deviations.

Fig. 3 presents four cardinal vowel diagrams each showing 20 mean judgements of one judge. Each position is based on his judgements of the four vowel realizations per prototypical vowel position. A comparison of the diagrams shown in fig. 3 reveals the differences between the perceptual behaviour of the subjects.

5.1. Statistical analysis

We used several bivariate three-way linear ANOVAs to analyse the perception data. Trivially, the factor 'vowel' showed significant influence on the perception results (F(19,171) = 194.58, $p < 0.001$).

A significantly large effect on the perception results came out for the factor 'speaker' (F(3,171) = 21.33, $p < 0.001$) and likewise for the factor 'judge' (F(3,171) = 30.08, $p < 0.001$). Furthermore there was no interaction found between 'speaker' and 'judge' (F(9,171) = 1.62, $p = 0.112$). On the other hand significantly large interaction took place between 'vowel' and 'speaker' (F(57,171) = 7.44, $p < 0.001$), as well as 'vowel' and 'judge' (F(57,171) = 2.14, $p < 0.001$).

Since our main concern was to investigate L1 interference, we have then transformed the 2 four-level factors 'speaker' and 'judge' into 2 two-level factors 'speaker-origin' and 'judge-origin'. By applying another bivariate three-way ANOVA the same significance pattern has been received with one exception (see tab. 1): there was no significant interaction found between 'vowel' and 'judge-origin' (F(19,259)=1.17, $p = 0.282$).

Effect	F	p
vowel	F(19,259)=111.55	$p < 0.001$
speaker-origin	F(2,258)=14.84	$p < 0.001$
judge-origin	F(2,258)=10.44	$p < 0.001$
vowel×speaker-origin	F(19,259)=4.56	$p < 0.001$
vowel×judge-origin	F(19,259)=1.17	$p = 0.282$
speaker-origin×judge-origin	F(2,258)=0.492	$p = 0.612$

Table 1. Results of the bivariate three-way linear ANOVA on the vowel judgements.

These results show clearly that our subjects neither produced the same vowel quality (fig. 2) nor did they perceive the same vowel quality (fig. 3). There is significant inter-individual variance as well as significant variance regarding the origin of the speakers.

5.2. Qualitative analysis

Despite the fact that only 7 of the 20 initial points (35%) had their positions on one of the external or internal lines of the cardinal vowel diagram (see fig. 1) more than 59% of points (190 of 320) were plotted there during the perception experiment. This discrepancy could be a result of unsureness or convenience in plotting points on rather visible lines than within the empty space of the diagram. However, dimensions of height and backness could easily be distorted if a subject is unsure about his judgements or prefers drawing convenience.

We also examined deviations between lip roundings of the initial vowels and the corresponding judgements. The stimuli which had to be produced as rounded were judged as unrounded in approx. 24% of cases. The unrounded stimuli were judged as rounded in approx. 9% of cases.

Since the durations of vowel realizations were not produced constantly among different speakers and vowels it could have had an uncontrolled influence on perception. Therfore we compared durations of stimuli showing poor lip rounding discrimination with durations of stimuli demonstrating well discriminated lip rounding. It seems that vowels which had durations of approx. 600–700 ms were judged more consistently than shorter or longer vowel realizations. This assumption is preliminary, and since our data is not sufficient for a more precise analysis further recordings are required.

The second and presumably the more important factor which affected the number of inconsistent judgements made with respect to the lip rounding was the quality of the initial vowel itself. In fact, 50% of judgements were inconsistent in case of the German prototypical vowel phonemes /ø/ and /ɔ/; 38% in case of the Russian vowels /ɨ/ and /u/; 31% in case of the German vowels /œ/ and /ʏ/. The points of these six vowel sounds are more centralized than the majority of the other 14 vowels and seem to have weaker articulatory-perceptive links to the values of the primary cardinal vowels.

One of the important results obtained by Lisker (e.g. Lisker 1989 [6]) was that lip position is not readily inferred from the acoustic signal and therefore there could be a general failure to decide whether the vowel had been produced with or without lip rounding only on the basis of auditory perception by ear. Taking into consideration our rather small pool of data we would like to restrict this statement to an assumption that especially the rounded vowels proved difficult to discriminate. The only unrounded vowel which was poorly discriminated was the Russian vowel /ɨ/ whose centralized position within the space of the diagram could have been unusual to the speakers of German (wrong judgements were received from speakers of German twice as often as from the speakers of Russian).

We would like also to recall the words of Abercrombie (Abercrombie 1967 [11] that it is extremely difficult to apply the cardinal vowel technique of description to recorded versions of vowels, because the investigator needs to see the speaker in order to judge the contribution of the tongue posture to the vowel quality that he hears in the light of what he can see of the lip posture. If there is no information on the lip posture one could be seriously misled in respect to tongue posture.

6. SUMMARY

We began our paper with the discussion of the question as to what the phonetically trained subjects need to know in order to be able to produce any vowel sound with the help of the IPA diagram as well as to plot any recorded vowel sound as a certain point within the space of the diagram. We mentioned three basic dimensions of vowel sounds (height, backness, rounding), values of primary cardinal vowels and proportions of the IPA diagram as necessary tools which could make this operation possible. A brief review of the past of the IPA diagram and particularly of the history of devising the diagram by Daniel Jones has been made. We also mentioned the basic principle of teaching values of cardinal vowels in phonetic classes — oral instructions by a teacher of phonetics.

On the one hand we were concerned with the fact that a teacher himself is a speaker of a particular language and could (at least theoretically) suffer from L1 interference. On the other hand we questioned the technique of testing phonetic capabilities of students by providing them with recorded vowels for auditory perception.

In order to investigate these questions we carried out a cross-language experiment with phonetically trained subjects who judged recorded vowels produced by themselves. We found out that neither vowels articulated and judged by the same subject nor vowels articulated and judged by different subjects were of the same quality. The data we received, presented in fig. 2, 3, 4, and analysed statistically (tab. 1), shows significant deviations resulting from inter-individual variance and from the L1 of the subjects.

We believe that despite the small pool of data we obtained by means of our experiment a general observation could be made: it should not be expected that producing vowels given as initial points within the space of the IPA vowel diagram would lead to reliable judgements which match exactly the original positions even if highly qualified subjects take part in the experiment.

However, if judgements are averaged over a large number of individual judgements then confidence intervals become smaller. A comparison of fig. 4 with fig. 1 indicates that some of the mean judgements deviate less from their initial positions (e.g. German /i/, /o/, Russian /ɛ/) and could confirm the strong consistency of judgements reported in Ladefoged 1967 [7] and Pfitzinger 1995 [12]. But other vowels (e.g. German /y/, /œ/, Russian /ɨ/, /u/) clearly verify the hypothesis of this study that there are L1 effects on vowel production and perception. In future work we intend to confirm our results with larger pool of data.

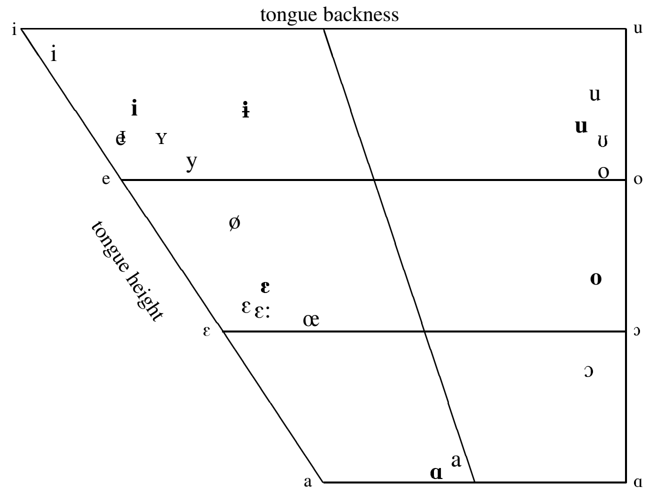

Fig. 4. 20 mean judgements of the initial vowel targets (see fig. 1) which were produced four times each, leading to 80 realizations again judged by four phoneticians yielding 320 judgements.

7. REFERENCES

[1] D. Jones, *An outline of English phonetics*, W. Heffer & Sons Ltd., Cambridge, 9. edition, 1962.

[2] M. Ashby, "A note on the vowel quadrilateral," *J. of the Int. Phonetic Association*, vol. 19, no. 2, pp. 83–88, 1989.

[3] International Phonetic Association, "Report on the 1989 Kiel convention," *J. of the Int. Phonetic Association*, vol. 19, no. 2, pp. 67–80, 1989.

[4] P. Ladefoged, *A course in phonetics*, Harcourt Brace College Publishers, Fort Worth, 3. edition, 1993.

[5] D. Jones and D. Ward, *The phonetics of Russian*, University Press, Cambridge, 1969.

[6] L. Lisker, "On the interpretation of vowel 'quality': the dimension of rounding," *J. of the Int. Phonetic Association*, vol. 19, no. 1, pp. 24–30, 1989.

[7] P. Ladefoged, *Three areas of experimental phonetics*, Oxford University Press, London, 1967.

[8] F. Nolan, "2.2 Vowels," *J. of the Int. Phonetic Association*, vol. 18, no. 2, pp. 69–74, 1988.

[9] International Phonetic Association, Ed., *Handbook of the International Phonetic Association. A guide to the use of the International Phonetic Alphabet*, University Press, Cambridge, 1999.

[10] L. V. Bondarko, *Fonetika sovremennogo russkogo jazyka: uchebnoje posobie*, Izdatelstvo S.-Peterburgskogo universiteta, 1998.

[11] David Abercrombie, *Elements of general phonetics*, University Press, Edinburgh, 1967.

[12] H. R. Pfitzinger, "Dynamic vowel quality: A new determination formalism based on perceptual experiments," in *Proc. of EUROSPEECH '95*, Madrid, 1995, vol. 1, pp. 417–420.

[13] H. R. Pfitzinger, "Vokalperzeption und akustische Merkmale," M.S. thesis, Institut für Phonetik und Sprachliche Kommunikation der Universität München, Aug. 1994.

[14] O. I. Dioubina, "Interferenzen bei der Perzeption der Vokale des Russischen und des Deutschen," M.S. thesis, Institut für Phonetik und Sprachliche Kommunikation der Universität München, Aug. 2001.