"OBSERVER EFFECT" IN LATE 19TH AND EARLY 20TH CENTURY MEASUREMENTS OF VOWEL CHARACTERISTIC TONES

Ulyana Kochetkova[1], Pavel Skrelin[2]

[1,2]Saint-Petersburg State University
ukochetkova@phonetics.pu.ru, skrelin@phonetics.pu.ru

ABSTRACT

In the late 19th and early 20th century various tools and techniques existed for vowel characteristic tone measurements, including the use of such instruments as tuning forks and resonators. This subtle method demanding from the researcher a sensitive ear and a good training nevertheless remained subjective and depended to a great extent on the explorer's will. Contrary to modern data descriptions, most of vowel measurements were given as precise single values and not as value areas. Thus several questions arise: what are the possible reasons underlying the choice of a concrete value by a researcher? Could this choice be deliberate? Was it due to the measuring technique imperfection? What role could tradition and psychological aspect play?

In order to answer these questions, values suggested by Helmholtz, Koenig and Rousselot are analyzed in the present study in correlation with the descriptions of measurement methods existing at that time.

Keywords: vowel formants, music intervals, scales, tuning forks, French phonetics.

1. INTRODUCTION

The observer effect notion appeared only in 20th century in order to define the influence of the observer on the results of the experiment and on its very process, first noticed by Niels Bohr [9]. Although this term refers to quantum physics events, in its figurative sense it could possibly be extrapolated to the linguistic field as well.

The aim of the current study is to analyse the probable influence of ideas, presuppositions or experimental conditions on the measurements of the vowel characteristic tones in the late 19th and early 20th century. At that time, the term characteristic tone was used in parallel with the term resonance or resonance tone. It can be related to the present-day term formant. Although L. Hermann introduced [21] the latter in 1894, the term characteristic tone stayed in use even in the beginning of the 20th century.

One of the most subjective acoustic experiments consisted in defining vowel tones with the use of tuning forks [1, 5, 6, 8, 11, 15, 18]. This technique demanded not only an acute hearing from the experimenter, combined with a high degree of concentration, but also quite a special articulatory training. However, many scientists of that period, including Helmholtz, Koenig and Rousselot decided on this sophisticated method when exploring the quality of vowels in various languages.

Unlike today, most of vowels were described with only one formant [12, 21] that was perceived as a predominant tone. If one tries connecting it to the modern source filter theory, in most cases, this characteristic tone may be related to the F2 [19].

An important detail is that this tone was described through one precise value. The authors took into account neither cross-speaker nor within-speaker variability. In order to find underlying reasons of their choice, the relationship between the vowel tones descriptions, the researcher's thoughts and the measuring techniques has been considered in this paper.

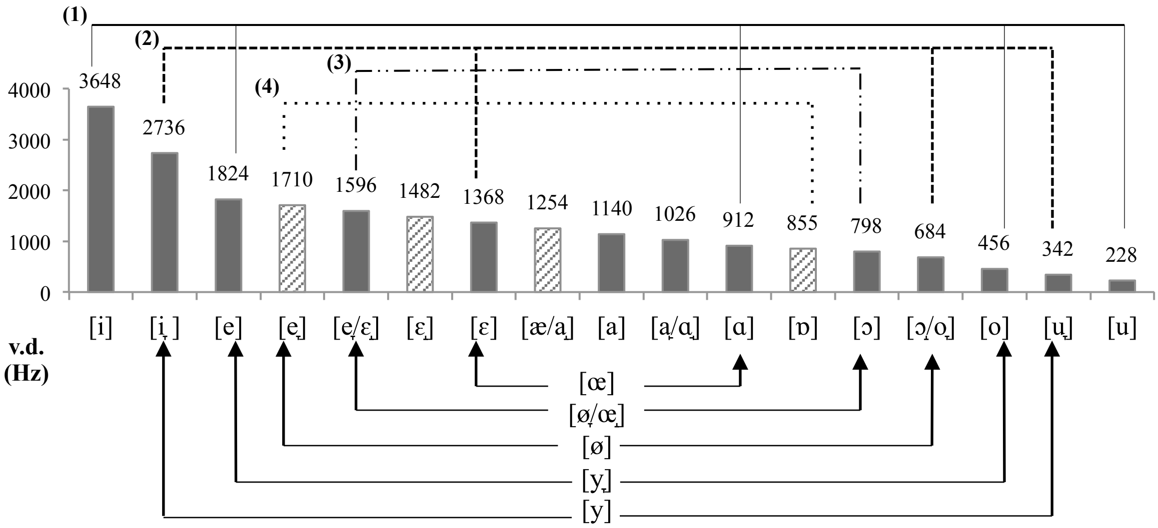
A point of departure for the current analysis was the description of the French oral vowel system by the "father of experimental phonetics" Abbot Jean Pierre Rousselot [14, 15, 16, 17, 18]. His results and commentaries have been compared to those made by his predecessors Hermann von Helmholtz [6] and Rudolph Koenig [8].

2. VOWEL TONE DESCRIPTION

2.1. French oral vowel system described by Rousselot

Rousselot provides an accurate description of the characteristic tone values for all French vowels, including their variants [15, 16, 17, 18]. As the terms "phoneme" and "allophone" were not used at that time, he indicates them as "close", "middle" and "open" vowels (for detailed analysis cf. [19]). Only front rounded oral vowels [y], [ø], [œ] and their variants have, according to him, two bright perceivable tones: the tone of the unrounded front vowel coupled with the tone of the back vowel [17]. For the rest of the vowels Rousselot indicates only one characteristic tone, though assuming the presence of other less perceivable tones in the vowel timbre. He also gives additional variants defining them as "regional", even if they belong to other languages [17, 19].

Figure 1. Schematic diagram of the French oral vowel system described by Rousselot [18]. Dark bars indicate French oral vowels including their combinatory and positional variants; light bars indicate additional "regional" variants. Front rounded vowels are shown below the histogram; arrows indicate two tones that compose the vowel timbre. Different types of lines above the histogram represent four series of octaves. Rousselot's terms are translated into IPA symbols; 1 v.d. = 1 Hz.



2.1.1. Peculiarity of proportions in Rousselot's French oral vowel system description

The schematic diagram (Fig. 1) demonstrates frequency values of the characteristic tones suggested by Rousselot for the French oral vowels and their variants, including additional "regional" ones. Front rounded vowels with their variants are shown under the histogram. Frequency is indicated in v.d. or "vibrations doubles", which was a French unit of measure equivalent to c.p.s. or "cycles per second". Both terms were in use before the unit of Hertz appeared in the 20th century [4, 19].

As one can see from the diagram, Rousselot perceived vowels F2 as a characteristic tone, excepting two /i/s, for which F3 seems to be the most relevant resonance. This observation correlates with the modern French vowel perception data. Values of [u] and [o] may also correspond to the F1, as it was shown in the previous analysis [19].

An amazing fact is that the tones on the diagram may be grouped into four series of octaves (as the lines in the upper part of the diagram show). These very octaves can be found in the composed tone ratios of the front rounded vowels: one octave for [ø̞/œ̞], two octaves for [y̞] and three octaves for [y].

Besides, one can clearly perceive that the sequence of vowels [o, ɔ̞/o̞, ɑ, a, ɛ, e̞/ɛ̞, e, i̞, i] represents a series of overtones of the sound [u], as long as they are all multiples of 228 v.d. (Fig. 1).

2.2. In search of octaves: results of Helmholtz, Koenig and Rousselot

What are possible reasons for such proportions in Rousselot's series of values? Who could influence his ideas?

As it can be seen from Rousselot's treatises [15, 18], he was very well acquainted with and influenced by the famous work of Hermann von Helmholtz "On the sensation of tones as a Physiological Basis for the Theory of Music" [6]. This author was the first to define vowel timbre through two characteristic tones [12, 21], except for [u], [o] and [a]. According to him, vowels [o], [a] and [e] represent a series of octaves, if one consider the second (higher) tone for [e] and not its first (lower) tone. These vowels give resonance at the notes b^1, b^2 and b^3 respectively, i.e. at b flat of the first, second and third octave [6, 22].

Rousselot also quotes the results of another famous acoustician, Rudolph Koenig, who was Rousselot's teacher, colleague and friend [17]. Koenig discovered with a great surprise [8] that there was the interval of one octave between elements in the range of the "main" German vowels [u], [o], [a] and [i]. All these vowels resound at the note b, starting from the small octave, then rising by steps of one octave for [o], [a], [e] up to [i]. Koenig reproduced these very vowels in the sets of tuning forks accompanied by Helmholtz resonators [11].

After citing Koenig’s data, Rousselot states with an unconcealed enthusiasm [18] that he found the same relationship between his vowels, “his” being used in a literal sense, as Rousselot describes his own pronunciation [19]. He assumes that the series of vowels are transposable from language to language or within one language and can be related with musical scales and tonalities [18].

2.2.1. Transposing octaves

Rousselot transposes Koenig’s octaves, as it can be seen in Fig. 1, series (1). However, these “mythical” parallels with the results of the above mentioned authors on the one hand, and with the musical tradition on the other hand, do not satisfy Rousselot. As long as there exist more than five vowels in the French language, he tries to build up a new octave series [18], now for the “middle” vowels, i.e. for the combinatory allophones of the French phonemes [16]. This sequence of octaves made by “middle” vowels is presented by the series (2) (Fig. 1): [u̝], [ɔ̞/o̝], [ɛ] and [i̝].

2.2.2. Creating new scales

Rousselot tries not only to find octaves, but also to discover some equal intervals that would separate vowels or their variants [18]. He concludes that the octave should be divided into eight equal parts, and not into twelve parts (semitones), as in musical scales. Thus, Rousselot adds some rare regional variants, as well as vowels from other languages in order to make his newly invented system complete. The very possibility of such a “musical” approach is assumed as a matter of course.

3. TECHNIQUE OF VOWEL TONE MEASURING WITH TUNING FORKS

Many new experimental apparatus appeared in the second half of the 19th century, allowing a much more objective research of sound in general and speech sounds in particular [1, 10, 11, 12]. However, such illustrious scholars and inventors as Helmholtz, Koenig and Rousselot continued using tuning forks for the definition of vowel characteristic tones. What was their method and how could it affect their results?

3.1. Method

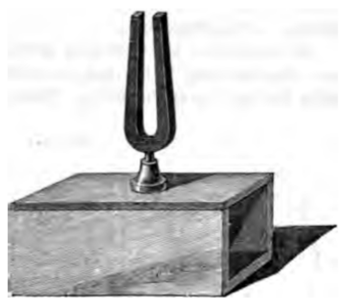
There existed various types of tuning forks and experiments with their use [2, 11, 18, 19, 20]. Tuning forks could be used with or without Helmholtz resonators. They could also have a resonating box. They could be a part of a complicated apparatus [11]. Nevertheless, the further analysis will be focused on the technique used by all the authors in order to obtain the results described above (see section 2.2).

Helmholtz [6] provides us with a wonderful description of his experiment with a tuning fork. According to him, “… if a b` < flat > tuning-fork be struck and held before the mouth while “o” is gently uttered, or the “o”-position merely assumed without really speaking, the tone of the fork will resound so fully and loudly that a large audience can hear it. The usual a` tuning fork of musicians may also be used for this purpose, but then it will be necessary to make a somewhat duller “o”, if we wish to bring out the full resonance.” [6, p. 158]. He also gives another comment: “it is particularly remarkable what little differences in pitch correspond to very sensible varieties of vowel quality in the neighborhood of *a*” (i.e. “la”) and he recommends philologists who whish to define the vowels of various languages “to fix them by the pitch of loudest resonance” [6, p.159]. Koenig and Rousselot give a similar description [8, 18].

3.2. Instruments

An easy explanation of the vowel tones association with notes of Western European musical scale would be the repertoire of tuning forks used by Helmholtz, Koenig and Rousselot. It is true that in the 19th and even in the early 20th century, in most acoustic, psychological or physiological laboratories all over the world, a set of tuning forks for the C major scale (Fig. 2) was almost canonic [5, 11].

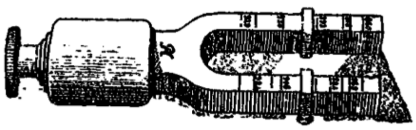
Figure 2: Tuning fork on the resonating box; illustration from Helmholtz’s work [6].



Helmholtz gives an illustration of such a tuning fork in his treatise (although he also used forks without a resonating box) and complains [6, p.160] of the lack of high-pitched forks for the precise definition of [i]. He also deplores the fact that his tuning forks allowed measuring with a precision of one semitone only [6]. However, Helmholtz prefers using tuning forks for other vowels study, defining for some of them the second, less perceivable tone [6]. Many of his observations seem to remain valid today [21].

In order to improve the situation, Rudolph Koenig elaborated the tuning fork provided with special brass sliders (Fig. 3), as he proudly claimed [8, 11]. Rousselot also used these adjustable tuning forks [14, 17, 18]. Such instruments enabled a continuant gradation of tone frequency, surpassing most of the acoustic instruments of that time [11]. Therefore neither Rousselot, nor Koenig were limited to the semitones of musical scale in their observations. However they kept searching for parallels with western music tones, intervals and scales.

Figure 3: Tuning fork with sliders; illustration from Rousselot's "Principles of experimental phonetics" [18].



4. PSYCHOLOGICAL ASPECT

One might suppose that validation of frequency by means of human hearing alone could lead to mistakes. Nevertheless, this is hardly imaginable, because Helmholtz was a renowned author of music perception theory, Koenig started his career as a violin maker [1, 11] and Rousselot was supposed to have a music education as well.

Another possible explanation of the results could be a kind of subconscious "adjustment" of the researcher's articulation to the tuning fork's frequency. A. J. Ellis, who translated the Helmholtz's famous work [6] into English, made a very interesting remark in footnotes in this relation. He assumes that even with the use of special apparatus there may be a "great difficulty <…> on account of the same speaker in his vowel quality for differences of pitch and expression, the want of habit to maintain the position of the mouth unmoved for a sufficient length of time to complete an observation satisfactorily, and, worst of all, the involuntary tendency of the organs to accommodate themselves to the pitch of the fork presented" [6, p. 159]. The fact that in this subtle experiment the researcher is at the same time the experimentalist, the examinee and the measuring instrument, make these unconscious articulatory movements possible and may influence the results of the experiment.

5. ORIGINS OF MUSICAL NOTATION USAGE FOR VOWEL DESCRIPTION

The authors' presuppositions may also have an impact on the experiment results. For this purpose the tradition of vowels description should be studied.

Samuel Reyher [13] is supposed to be the first author who as early as in 1679 gave concrete values for vowel tones [12], defining them with musical scale notes and putting them on the musical staff. Three vowels: [u], [a] (its "most open and bright" variant) and [i] have intervals of one octave between them [13, p. 433]. One can find the same octaves range for these very vowels in some later works as well (cf. the table given by Viëtor [22, p.18]). Therefore perception and description of cardinal vowel tones as a range of octaves existed from 17th century onwards, though not universally accepted.

Another interesting fact is that Reyher, speculating on vowels, mentions the names of Agrippa, Jacobus Bonaventura Hepburnum, Giovanni Panteo and Fransiscus Mercurius van Helmont [13]. All of them, as well as Reyher himself, were well-known cabbalists and aimed at decoding the "Alphabet of Adam" in order to understand the mystery of nature and creation [3]. The main goal of their study was to decode the Hebrew alphabet and to define its main vowels. This idea can be found even in 19th century and seems to have had some influence on the number of Koenig's tuning forks in the set for five German vowels.

It should also be mentioned that in cabbalists' works, as well as in 17th century philosophy in general, a very particular attention was given to the musical notes and intervals. Authors tried to endow them with metaphorical meaning. An illustration of such a symbolism, which is rooted in the ancient Greek philosophy [3], can be found in the above cited work by Reyher [13]. Thus the search of concrete musical intervals between vowel tones may have its origins in the 17th century philosophy.

6. CONCLUSION

In the current study a very complicated technique of vowel tone measurements with tuning forks has been analyzed. Possible factors that could condition the results obtained by the authors have been considered. The psychological aspect seems to be of importance. However, this doesn't account for the authors' search for musical proportions in speech sounds. It allows to suppose that besides the psychological factor, the second important factor is the authors' way of thinking, influenced not only by their musical background, but also by the centuries-long cultural and scientific tradition.

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