The integration of phonetics and phonology

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Abstract. Almost a century ago, when Rousselot (1904) established the principles of experimental phonetics, he emphasized the need to develop experimental methods in linguistics and the fact that phonetics and phonology are one and the same domain. However since Trubetskoy (1939), and even earlier for some linguists, phonetics and phonology have been considered as two separate domains in the study of language. A century after Rousselot, the relation between phonetics and phonology receive new attention. The trends of experimental and laboratory phonology (Ohala & Jaeger 1986 and the collection of Papers in Laboratory (Kingston & Beckman (1990); Docherty & Ladd (1992); Keating (1995); Connell & Arvaniti (1995); Broe & Pierrehumbert (2000); Local, Ogden & Temple (2003); Gussenhoven & Warner (2002)) is now well established and makes that fundamental issues such as: the description of sound systems; the search of primitives; the type evidence; the nature of explanation; the nature of phonological representations and the type of experimental paradigms are now evaluated differently then when the two domains were considered separated by the structuralist and generativist frameworks. This new state of affairs leads to consider that phonetics and phonology are two faces of the same domain and that they have to be integrated to answer to the fundamental questions about speech in human languages as it has been proposed by Ohala (1990).

1. Phonetics and phonology

1.2. Phonetics

Let’s start by examining what is usually thought to be the domain of phonetics and phonology. Phonetics can be taken as the discipline that studies how speech sounds are produced and perceived, it is also considers various bio-physical aspects of speech such respiration and articulatory movements. Going back to the time of Rousselot, phonetics was defined as: ‘La phonétique est la science des sons du langage, c’est une branche de l’acoustique, des sciences naturelles, psychologiques et sociales. Cette complexité n’a pu qu’en retarder le progrès’. (Rousselot 1923). As one can see from his quotation, phonetics is considered as a science or part of the domain of science, it takes into consideration acoustics and therefore physical aspects of speech, psychological aspects –the way speech sounds are perceived–, and the social dimension of speech. The two latter aspects of phonetics are now developing rapidly in the frame of sociolinguistic (e.g. Foulkes and Docherty 2002) and psycholinguistic studies (e.g. Lahiri & Marlsen-Wilson 1991). However the two former aspects have known a continuous growth since the end of the XIXth century. Rousselot also clearly states that the complexity of the object (the various disciplines involved to study the phenomena) create a complication that is not always present in other fields.
1.3 Phonology

Most phonologists would likely accept that phonology studies the logical and functional and behavior of speech sounds. This implies the categorization of sounds or features, the mental representation and other cognitive aspects of speech sounds. The phonological literature of the second end of the XXth century is quite large and whatever the model considered, a central issue, for all trends, has been the relation with phonetics. From the early days of structuralism there has been a tendency to consider phonetics aside of the main core of language (and this have wrongly been attributed to Saussure, who was by training a Neo-grammian and therefore aware of phonetic issues). Because of this, in linguistics, the domain of speech sounds was mainly processed by phonology. This separation was stated explicitly by Trubetskoy (1939) who considered phonetics as rather in the domain of natural sciences and phonology as in the domain of linguistic studies. This was also the viewpoint of generative phonology since the beginning because it considered that phonology is a kind of program that is implemented into phonetics.

1.4 What are (some of) the questions that phonetics and phonology have to answer?

What characterizes any scientific endeavor or discipline is the question that scientists are trying to answer. More than likely, and even if the following list of questions is not exhaustive, most phoneticians and phonologists would consider the following questions as part of their research activities. How are acoustic features categorized? How do we explain the source of sound change? How does speech perception influences sound change? What can we say about the direction of sound change? How are allophones controled and categorized? Do we account for sounds better in terms of features or in terms of gestures? How can we account for articularatory control? What is the minimal distance between segments for them to be perceived? How can we can account for the emergence of sound patterns in ontogeny and phylogeny? What are the correlates of syllables? Are typologies of any use to explain sound patterns? What are the best primitives? What kind of explantion is required to explain the observed phenomena? What are the constraints acting on phonetics and phonological processes? How do we explain universals? What are the universals?

It seems quite obvious that to answer to all, or some, of these questions we need to integrate what is known in speech production and speech perception into phonetics and phonology.

2. Phonetics and phonology must be integrated, these are two faces of the same domain, the universe of speech sounds

However not all linguists have considered the separation between the two domain of speech so sharply as just evoked. For example, Rousselot (1904) in the first pages of his ‘Pincipes de phonétique expérimentale’ write a note to explain the difference between the terms phonetics and phonology and why the former was chosen: ‘term phonetics was introduced by Bréal and Baudry who were hesitating between phonetics and phonology because the latter could mean the science of murder ‘φονος’, Rousselot (1904: 2). From this remark (even if anecdotic), and most of Rousselot’s work, it is clear that the founder of experimental phonetics did not consider phonetics...
and phonology as separated domains. Later, Ohala emphasized this viewpoint in numerous publications (e.g. Ohala 1990, 1995). This is the point that will be defended in this paper, namely there is only one domain in the universe of speech sounds and that the traditional separation of phonetics and phonology has to be abandoned for the integration of these two sides of the universe of speech. How can we do this? The proposition is: by taking into consideration that phonetics and phonology are experimental disciplines. Since Rouselot (1904) most linguists don’t doubt of the fact that phonetics is an experimental discipline. However it is only since the work of Ohala (e.g. 1974, Ohala & Jaeger 1986) that the experimental nature of phonology has been explicitly considered. What does it mean integrating phonetics and phonology? Basically that there is a physical and a cognitive side to speech and that they have to be integrated if we want to be able to explain the phenomena that we observe in the universe of speech.

The interaction between the physical and the cognitive aspects of speech sounds is enhanced in the model of articulatory phonology (Browman & Goldstein 1989, 1992), and in the emphasis made by Hume & Johnson (2001) on the role of perception in phonology. Whatever the limits of articulatory phonology and whether or not one agrees with the model, it is difficult not to acknowledge that it is a serious tentative to integrate the domains of phonetics and phonology. Indeed, in articulatory phonology, phonological units are discrete gestures having an abstract and a concrete (dynamic) side. This model of phonology conducted to take into account time (the dynamic aspects of gestures) into phonology and allowed to consider processes such as assimilation and epenthesis, for example, as variations in the execution or phasing of gestures.

The propositions made by Hume & Johnson (2001) on the interplay of speech perception and phonology allowed to think about the integration of the cognitive aspects of speech sounds in phonology. Hume & Johnson (2001: 6) show how phonological systems influence speech perception (for example how listeners are more adept at perceiving sounds of their native language than those of a second language). They also show the influence of speech perception on phonological systems, by the failure to perceptually compensate for articulatory effects, by the avoidance of weakly perceptible contrasts and by the avoidance of noticeable alternations. The influence of speech perception in phonology is particularly obvious on what Hume & Johnson call phonological repair strategies that can either preserve contrasts (epenthesis, dissimilation & methatesis) or sacrifice contrasts (assimilation and deletion). What is important in Hume & Johnson (2001: 20) model is the emphasis made on the fact that the interplay between speech perception and phonology is defined to include the cognitive and formal representations of phonological systems.

3. Experimentation in phonetics and phonology

Whatever one can think of this, experimental methods have been used for a long time to study speech, and the work of Rousselot still provides a tremendous example of the benefit of experimentation for the study of speech and phonology under different aspects including dialectology. However the results and methods of experimental studies have not been sufficiently incorporated into the framework of phonology, maybe because of what Rousselot (1924: 1) thought almost a century ago :‘…les procédés des sciences expérimentales sont assez étrangers aux linguistes. Une sorte de terreur supertitieuse s’empare d’eux dès qu’il s’agit de toucher au mécanisme le plus simple. Il
fallait donc...leur faire entrevoir le champ immense que l’expérimentation ouvre devant eux’.

The idea to treat language as an experimental discipline was in the mood of the time and for Rousselot, by becoming experimental, ‘la phonétique prenait ainsi sa place à la base même de la nouvelle science grammaticale’ (1923: 5) (in this he was referring mainly to historical aspects of language). This later quotation has to be related to a quotation of Bréal (1897) made in his ‘Leçon d’ouverture’ at the College de France in 1923: ‘Dans vingt ans on ne comprendrait pas un cours de grammaire comparée sans laboratoire’ (1923: 13). The least that we can say is that it was a bit too optimistic but the last decades of the XXth showed some move in this direction.

Going back to experimental phonetics, we can see that Rousselot was very conscious of the historical developments related to speech studies: ‘on peut dire que la phonétique expérimentale se rattache à l’école phonétique du XVIIIème siècle, dont, seuls, les constructeurs d’automates surent tirer profit’ (1923: 7-8). Here Rousselot likely make explicit reference to the work of von Kempelen and Kratzenstein (we will come back to those issues when discussing the role of engineering in speech).

In his ‘leçon d’ouverture’ at the Collège de France, debating issues related to phonetics and linguistics, Rousselot states a crucial point (that one can still hear today) about the relation of science and language and about the status of experimentation: ‘On a refusé à la linguistique le titre de science, en alléguant pour motif qu’elle emprunte sa méthode à l’histoire, qu’elle enregistre simplement les faits sans pouvoir les reproduire, impuissante par conséquent à atteindre la certitude que donnent les sciences proprement dites’(1923: 17). Thus Rousselot was questioning this position and was advocating for a science of language in which phonetics was a part.

Debating issues related to experimental phonetics, Rousselot raised a program that any speech scientist can still adopt nowadays: ‘Elle (experimental phonetics) demande à l’organisme lui-même de lui en révéler les conditions physiologiques ; elle dégage les éléments actifs, qui, à un certain moment de l’évolution ont été mis en présence, puis elle cherche à les reconnaître dans le trésor du parler humain ; enfin, quand elle a été assez heureuse pour les rencontrer dans une même bouche, elle les réunit ; et alors, aussi sûrement que s’il s’agissait d’une manipulation de chimie, elle voit se reproduire le phénomène attendu. C’est là l’oeuvre propre de la phonétique expérimentale’ (1923: 17).

Let’s see this program in more details. First physiological conditions must be studied, then active elements showed. This takes into account the various parameters of the speech production mechanism, such as articulatory movements and aerodynamic conditions, and also takes into consideration the physiological aspects of speech in their active aspects. Then talking about evolutionary aspects he evokes variation, sound and dialectology, the three areas of speech where dynamic aspects are the most clearly observable. Note that there is a striking similitude of thought between Rousselot and Ohala in this respect, since both made the study of sound change a central issue in their research. By ‘trésor du parler humain’ one has to understand everything that can be observed in any language spoken in the world. Therefore what is proposed is to collect data on any form of human language in the most objective possible way. The last part of the quotation shows that Rousselot had clearly understood the necessity to be able to recombine elements of speech and to be able to reproduce them in an experimental way.
and therefore in laboratory conditions. Here again there is a parallel with Ohala (1974) who states that one of the main goals of this kind of endeavor is to be able to reproduce the phenomenon that is under investigation, in laboratory conditions (i.e. in controlled conditions). Is it to say that linguists, in the boarder sense of the word, are not part of this work? Clearly not: ‘...pour certains problèmes de linguistique, l’expérimentateur ne saurait se passer de la collaboration du linguiste compétent’ (1923: 21).

To sum up and to quote Rousselot once more, we could say that: ‘La phonétique expérimentale : Ce n’est plus une simple nonmenclature des sons articulés, ni le chapitre détaché d’une grammaire, ni l’histoire de matériel phonétique d’une famille de langues. C’est la science des sons du langage, science universelle par son objet et sa méthode’. (1923: 23).

When one says that there is no interface between phonetics and phonology and that the two domains must be integrated, several important objections and questions are usually made about the division of labor between the bio-physical aspects of speech and the more cognitive side of this research. Therefore how are we going to take into account for the abstract sides of speech such as representations and categorization? One possible way to answer is to accept the view that is proposed by (Ohala 1990 : 168): « My own view is that between phonology and phonetics, phonology is the superordinate discipline, not because it has accomplished more or is better developed -the opposite may be true- but simply because it looks at and seeks answers to a much broader range of phenomena involving speech behavior’. What this means is that phonetics is part of phonology and that phonology still awaits experimental paradigms to study cognitive aspects of the universe of speech sounds. It seems that the very fast development of psycholinguistic and cognitive studies offers phonologists a way to develop such paradigms. The problem is to find a way to integrate the knowledge of phonetics within these news paradigms. One possible way of doing this is again to follow what Ohala (1990) proposes. This proposition states that whatever the model of phonology adopted, phonological theory must be based on models that incorporate parameters coming from the sub-systems involved in speech communication. Among these, there are principles relating vocal tract shape and acoustic output, some known aerodynamic principles, and finally some of the principles that explain how our auditory system extracts information from the acoustic signal. In addition, information concerning feedback and control processes, such as those proposed by Perkell (1981) and MacNeilage (1981), should be included in such a theoretical framework. Therefore phonological theory must also incorporate known and well established facts from models of speech production and speech perception.

The question of experimentation can also be discussed in a way very similar to what was evoked by Bernard (1865) when he established the principles of experimental medicine. For Bernard, it was much harder to make experimentation in medicine than in any order science and because of this experiments were indispensable. To quote Bernard (1865: 2-3): ‘the more complex the science, the more essential it is, in fact, to establish a good experimental standard, so as to secure comparable facts, free from sources of error’. The comparison with language is striking and we might be at the time, in the study of language, comparable to the state of medicine at the time of Bernard. No one will doubt that language is a very complex phenomenon and that to understand the phenomena that we observe, many disciplines are necessary. Several examples will be given later in which it is clear that : without combining physiology,
acoustics, aerodynamics and various experimental paradigms taking into account perception and cognitive aspects of speech, it is difficult to find any explanation to the phenomena that we observe.

4. How phonetics and phonology are integrated

The program proposed by Rousselot for experimental phonetics (see section 3) clearly states the necessity to study any possible language to account for variation and for the various possibilities in speech production. This program seems obvious but it is still not enough incorporated into general accounts of speech. However there are important exceptions to this, such as for example, Catford (1977) and Ladefoged & Maddieson (1996). If one considers experimentally based descriptions of speech sounds and of sound systems, it would be difficult not to acknowledge that the description of many phenomena found in the world’s languages did not contribute to a better understanding of speech production and perception. A phenomena like: tonogenesis has been, without doubt, a major contribution in the understanding of speech.

4.1 Tonogenesis and sound change

Tonogenesis, i.e. the development of contrastive tones on vowels, as a compensatory mechanism for the loss of consonantal contrasts at syllable-initial or syllable final position, is a good illustration of the integration of phonetic and phonology. This mechanism was first identified by Haudricourt (1954) in Vietnamese, and was explicitly formulated by Matisoff (1973, 1999). Basically it states that, in languages where the mechanism appeared, the loss of a final laryngeal consonant */-h/ (the later often from an earlier */s/) had a raising or lowering effect on the syllable’s pitch contour (Matisoff 1999). On the other end, the loss of a voicing contrast in initial position typically led to tonal split. As Matisoff (1999: 4) emphasizes ‘Tone is by no means a simple matter of relative pitch, but rather a complex bundle of features, including phonation type, tongue position, pharyngeal tension, vowel length and contour’. Tonogenesis is a typical example of sound change that can be described in the terms of Haudricourt, i.e. by describing the process and the regularities observed but if one wants to give an explanation to the process it seems obvious that that the interrelationships between the phonetic mechanisms just mentioned and the opposition between higher pitch and lower pitch has to be explained. Matisoff (1999: 5) presents this fundamental opposition as tense vs lax laryngeal syndromes. Tense-larynx syndrome includes (higher pitch/rising contour, association with -h, voicelessness, retracted tongue-root, creaky laryngeal turbulence, larynx tense and/or raised= reduced supraglottal cavity while lax-larynx syndrome includes lower pitch/falling contour, association with – h, voicedness, breathiness, advanced tongue root, rasping laryngeal turbulence, larynx lax and/or lowered=distended supraglottal cavity. What Matissof’s classification means is that we can identify the phonetic source of the tonogenesis mechanism but that we still have to explain how this is categorized in the phonology of the languages where it happens. The phonological aspects of the phenomenon are reflected by the fact that a contrast is maintained between two syllables or two words in order to maintain a semantic distinction. We can therefore identify three levels in the phenomena, (i) the observed facts in terms of process and distribution, (ii) the phonetic nature of the phenomena, i.e. the Tense-larynx syndrome and (iii) the categorization process. One might ask where are the representations in terms of features. The answer is
that it is just a way to systematize point (i) in that it allows to use a notational tool that helps to identify the phenomena on a descriptive basis. No feature analyses of the kind commonly used by phonologists allow to explain the nature of the phenomena. The explanation comes rather from the way phonetic cues are categorized. For example, Hombert et al. (1979) have shown that the development of tone after voiced and voiceless obstruents can be explained by reference to articulatory and auditory facts. The voicing distinctions in prevocalic position causes small Fo perturbations which are perceptible and in certain circumstances may be exaggerated and lead to the development of tone. The crucial factor is here the amplification of these perturbations. Small Fo perturbations immediately after voiced and voiceless stops are showed in the following Figure.

The way phonetic cues are categorized might simply reflect part of the general capacity of humans to categorize information. Turning to universal aspects of phonological systems, the processes identified by Haudricourt and Matisoff and the phonetic features identified proved to be valid in order studies of tonogenesis such as (Leer (1999) in Athapaskan; Haacke (1999) in Khoekhoe, Sagart (1999) in Chinese and Kingston (2003) in Athapaskan. Therefore one can hypothesize that tonogenesis is based on an universal mechanism that implies specific phonetic mechanisms and the way acoustic cues are categorized.

5. Conclusion

All phonological process and phenomena can be related to experimental data, i.e. on carefully made observations. However, some experiments are of a more sophisticated kind than others. These are the experiments that require the manipulation of some parameters in laboratory conditions. This shows that there are experiments that can be done in the laboratory to test hypotheses made in phonology. What is also fundamental to understand is that considering phonetics without phonology and vice versa considerably weakens the type of explanation that can be proposed to explain speech phenomena in languages. Every phonological phenomena is better explained if everything that we know about the acoustic, articulatory, and aerodynamic constraints that act on speech is taken into account.
Constraints refer to an important issue in recent phonological models such as Optimality Theory (Prince and Smolensky 1993). There is one fundamental way in which the approach taken here differs from a model such as Optimality Theory. Constraints are viewed as the universal forces shaping spoken language. These are production constraints: neurological, anatomical, physiological, aerodynamic and constraints stemming from the mapping between vocal tract shape and the resulting acoustic signal as well as perceptual constraints: such as peripheral and central auditory transforms of speech. Both production and perception constraints refer to asset of first principles that determine the way they act and interact. There are therefore not taken as a tool to represent or to systematize observations made on the behavior of phonological systems. It seems indeed that some of the regularities observed in languages can be accounted by physiological facts that are the constraints on the mechanism of speech production.

The discussion on tonogenesis refers to a type of sound change reflecting a phonological phenomenon, in this case the appariation of tone as a phonological category in a language. The observed facts are reported in terms of processes and distribution, then the phonetic nature of the phenomena is enhanced and finally categorization processes are discussed. For tonogenesis, as for every phenomena about sound change, it can be shown that a fundamental question to answer is what and how are phonetic cues categorized. This process of categorization is fundamental when one refers to phonological processes. As proposed earlier, this might simply reflect part of the general capacity of humans to categorize information (See e.g. Edelman 1987 for more details). Therefore one can ask if there is any specificity to categorization in phonology. This is an open and a fundamental question to the domain of phonology that will likely keep phonologists busy for a long time. One important point about categorization is to understand how phonological features can be associated with simple phonetic facts. The categorization of phonological features require processes which lie themselves on perceptual, auditory and cognitive capacities or constraints if they are to be incorporated in phonology. Phonological features are taken as descriptors of the properties of sounds systems rather than reflecting some innate properties.

All this shows that if constraints based on speech production and speech perception are taken into account, the description of phonological systems might be simplified. In order to do this, we must continue the hunt for a set of reliable primitives and to understand the basic constraints that explain the way the phonological systems of languages work.

Bibliography


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