Laboratory Phonology
Journal of the Association for Laboratory Phonology

Spreafico, L., & Vietti, A. 2022. Techniques and methods for investigating speech articulation: The centrality of instruments. *Laboratory Phonology: Journal of the Association for Laboratory Phonology*, 13(1): 2, pp. 1–8. DOI: https://doi.org/10.5334/labphon.8538

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Techniques and methods for investigating speech articulation: The centrality of instruments

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The editorial reflects on the role of instruments in phonetic sciences in the light of the themes addressed by the contributions in the special collection.

The history of phonetics—at least that of taxonomic phonetics (Ohala, 2004)—"goes back three millenia [sic]" (Koerner, 1993, p. 1). With regard to the branch of articulatory phonetics, over the course of time, the manner of studying phenomena of interest has changed a great deal, both with reference to the theoretical framework and to the research methodology (Tillmann, 2006). As regards the former, there has been a gradual shift from a non-experimental to an increasingly experimental approach. As regards the latter, there has been a shift from a non-instrumental to a preferably instrumental approach.

Indeed, in the prehistory and protohistory of phonetics (cf. Paconcelli-Calzia, 1961, quoted in Koerner, 1993), the investigation of speech articulation was impressionistic and based on two methods: speech proprioception[1] based on somatosensory information; and speech heteroperception[2] based on visual information, possibly interfered with by auditory information. Although these two methods have been descriptively valid and useful for shaping taxonomic articulatory phonetics (consider the accuracy and precision of the observations in Pāṇini's Aṣṭādhyāyī, cf. Allen, 1953), they are incompatible with the current experimental scientific method because the expectations, learning, and memories of the experiencer subjectively shape proprioception and heteroperception and thus make it unfalsifiable. Precisely for this reason, experimental investigation of the articulatory plane is usually based today on the adoption of an instrumental approach.

In articulatory research, however, the experimental and instrumental dimensions of the research must be kept distinct. In fact, until about the 17th century, non-experimental instrumental research was practiced, but at that time the study of articulation consisted of the instrumental dissection and anatomical investigation of laryngeal and supralaryngeal organs so as to describe the structure of the articulators that are not visually accessible and therefore to reconstruct or hypothesize *in vitro* their functioning.

In this sense, the oldest source could be represented by a drawing found in an Egyptian tomb dating back to about 5000 years ago that seems to depict a laryngoscopy or laryngectomy (Pahor, 1992; **Figures 1** and **2**).[3]

[1] Consider, for example, the approach taken by Robinson (1617) to illustrate the vocalic system, that Pfitzinger and Niebuhr (2011) define as an "introspective pseudo-articulatory approach."

[2] The perception of traits in other people.

[3] More recently both interpretations have been refuted by Blomstedt (2014), who believes that the drawings depict human sacrifices.

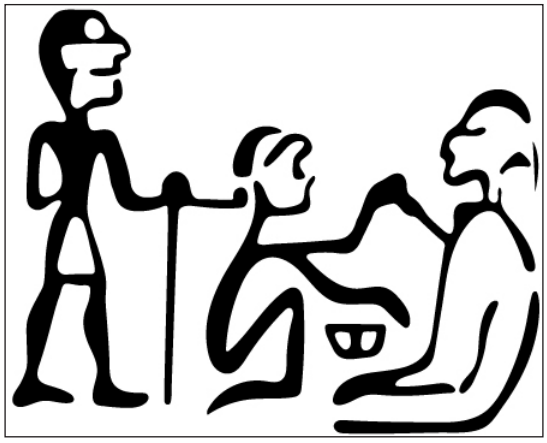

Figure 1: Particular of the label of Aha from Abydos depicting laryngoscopy, or laryngectomy, or tracheostomy, or human sacrifice. Copyright (1999) from *Early dynastic Egypt* by Wilkinson (1999, p. 230). Reproduced and reworked by permission of Taylor and Francis Group, LLC, a division of Informa plc.

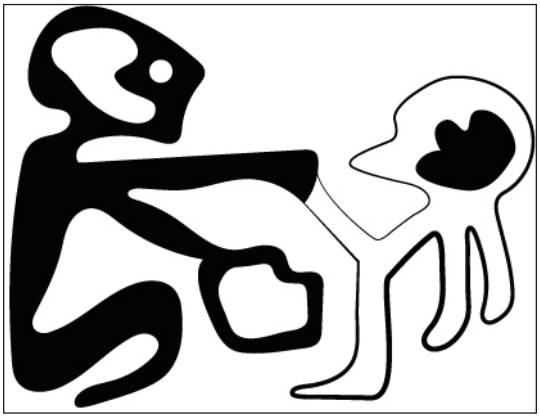

Figure 2: Particular of the label of Djer from Saqqara depicting laryngoscopy or laryngectomy, or tracheostomy. The scale is different from Figure 1. Copyright (1999) from *Early dynastic Egypt* by Wilkinson (1999, p. 230). Reproduced and reworked by permission of Taylor and Francis Group, LLC, a division of Informa plc.

However, even if anatomical knowledge was obtained through instruments, it did not necessarily imply physiological and even less articulatory knowledge, as evidenced by the fact that although dissections were widespread practices in ancient Greece, "the Greeks had only a vague notion of the mechanism of voicing" (Kemp, 2006, p. 472). In fact, the shift from an anatomy of laryngeal and supralaryngeal structures to a physiology of speech and then to an

articulatory phonetics began much later, probably around the beginning of the 17th century when for the first time the idea of an integrated study of the shape and function of the phono-articulatory organs emerged. One of the precursors of this approach was Girolamo Fabrici (Fabrici, 1600), who was among the first to write about 'speech' and 'hearing' instead of 'larynx' and 'ear.' From that point on, the chronicles report a series of scientific and technological attempts aimed at obtaining instruments that would allow researchers to observe in vivo and in real time and then also to record the movement of one or more articulators for subsequent analysis (Kochetov, 2020a, 2020b).

For this reason, the history of articulatory phonetics and the history of instruments and techniques for articulatory investigation largely coincide. In other words, the elaboration of new knowledge and theories on speech articulation are deeply intertwined with the development—in terms of both new tools and better performing tools (see Hoffmann, Mehnert, & Dietzel, 2011)—of instruments for the analysis of the phono-articulatory organs, as well as with the development of techniques for the analysis of the data collected with those instruments.

That this is the case is supported by reflections on the relationship between instrumental phonetics and other branches of the speech sciences, e.g., the position taken by Beckman and Kingston (2011) according to whom, the use of instruments has led to a split between phonetics and phonology; or by Demolin (2012) according to whom it is obvious—contrary to what is claimed by some phonologists—that the use of instrumental investigations has changed the course of phonology as well.

However, although it is acknowledged that instruments and methods of instrumental data analysis have played a fundamental role in the development of articulatory phonetics, it should also be noted that in phonetics, as in other experimental sciences, instruments are usually considered to have an ancillary role to theory. That is, instruments are usually considered to serve only to collect data that can then be used to falsify hypotheses. In this sense, instruments turn out to be a mere supplier of proofs for the subsequent evaluation of theories—i.e., being 'instrumental' to the cause—rather than to fulfil a true epistemological function.

However, treating the instruments for the investigation of speech articulation as if they were ancillary to the discipline itself does not do justice to them and risks losing sight of the fact that instruments "are constitutive of scientific knowledge in a manner different from theory, and not simply instrumental to theory" (Baird, 2004, p. 1). In this sense, the contributions of this special collection, which concern both articulatory data collection techniques and articulatory data analysis methodologies, are particularly significant because besides advancing the state of the art in their respective fields of application, they allow researchers to observe how instruments condition the observables, the experiment, and ultimately, the falsification and elaboration of new knowledge and theories.

The fact that the instruments condition the theory and are not ancillary to it, is illustrated first and foremost by the fact that even those instruments used to investigate speech articulation bring with them the typical limitations of instrumental measurement (Hughes & Hase, 2010), i.e., systematic errors, random errors, and mistakes.

In this respect, the contribution by Rebernik, Jacobi, Jonkers, Noiray, and Wieling (2021) is exemplary, because while dealing with published research on electromagnetic articulography (EMA) the authors (albeit not explicitly) detect both a source of systematic error and a source of random error. More precisely, after having reviewed about 900 scientific papers, Rebernik et al. observe that due to the different, and non-standardized positioning of EMA sensors on the tongue of informants, the possibility to compare the outcomes of the different research studies is limited. Secondly, they note a possible random error and observe that the availability of at least three different approaches to preparing EMA sensors before use can lead to different results of adhesion duration, and therefore to different data, and also to different falsifications of hypotheses.

The fact that instruments condition observables, hence theories, is also demonstrated by the fact that their use can affect the naturalness of speech. First because instrument sensors can disrupt articulation (Rebernik et al., 2021). Then, as often reported, because instruments can condition the posture and positioning of informants and therefore affect their way of speaking, for example by imposing on them unnatural postures in order to safeguard the sensors' ability to capture information of interest, as reported by Krause, Kay, and Kawamoto (2020) and Noiray et al. (2020). Lastly, as reported by Noiray et al., instruments can influence the behavior of some particular groups of informants, such as children, to the point that the instrument, or the environment in which the instrument is used, is required to be concealed so as not to be rejected.

Because of their size, delicacy, or cost, it is often that case that the instruments require research to be carried out in dedicated environments such as laboratories. On the one hand, the need to elicit data in the laboratory leads to criticism from some field researchers who sustain that laboratory data are not naturalistic and therefore irrelevant to general theorizations (but see the objections in Demolin, 2012). On the other hand, the desire to collect data as naturalistically as possible makes any project that aims to develop portable versions of already available instruments for articulatory investigation interesting and relevant for the study of phonetics, as noted by Krause et al. (2020).

The papers in this special collection on "Techniques and methods for investigating speech articulation" in *Laboratory Phonology* demonstrate that instruments are not ancillary but central to articulatory research for other reasons. One is that they show how the ability to handle the instruments themselves affects data and theory. In fact, as reported in all the papers collected here, the discussed instruments and methods for articulatory research require high levels of technical expertise and long phases of training in order to be used successfully. This may involve

the need to invest more resources in the project, for example, because it often involves having at least two people working on the data collection: one who supervises the instrument and the other who manages data elicitation (Noiray et al., 2020), or because it involves outsourcing the preparation of data for the analysis (Krause et al., 2020). In this sense, developing interfaces that allow the integration of information coming from several sources as proposed for the SOLLAR system discussed by Noiray et al. or in the paper on the UVA app presented by Gonzalez (2021) represents an advantage, because such systems allow researchers to simplify and optimize some phases of the data elicitation and analysis process, and thus speed up the work so that more data can be collected and analyzed in the same unit of time.

Furthermore, the need to rework and manipulate the data collected by the instrumental sensors in order to proceed with the theoretical analyses, which emerges from all the papers in this special collection, determines some necessary theoretical reflections that allow researchers to better focus on the nature of the instrument in articulatory research, namely its centrality. In fact, as noted by Boon (2015, p. 61) "instruments create an invariant relationship between their operations and the world, if and only if we abstract from the expertise involved in their correct use and the elaboration of the information they contain." This entails some reflections—certainly not new, but rarely made explicit in phonetics—namely whether science, and specifically articulatory phonetics, can test theories if they are based on experimental results based on the collection of apparently stable instrumental data which, however, entail a reworking. This is what, in Ackermann's (2016) terms, could be considered as the difference between testing hypotheses on *instrumental data* on the one hand and on *the meaning of instrumental data* on the other. The former coincides with the numerical values measured by the instruments, which are invariable under the same experimental conditions; while the latter correspond to the interpretations of the data themselves, which are variable according to the historical moment and the theory. In this sense, the contribution by Carignan et al. (2020) on real-time magnetic resonance imaging data is stimulating for at least two reasons. First, because it discusses how, for practical reasons of computational power limitations, only a part of the total amount of information generated and collected by the instrument is actually considered for the analysis. Moreover, it shows how applying two different statistical methods (FLMM versus GAMM) to the same database leads to results that are in agreement, yet not identical. But what if the difference between the two values were sufficient or necessary to verify or falsify a hypothesis?

To sum up, the information contained in the five articles of this special collection on "Techniques and methods for investigating speech articulation" in the Journal of the Association for Laboratory Phonology allows us to conclude that the constant interest in instruments and in the methods for the analysis of instrumentally recorded data testifies to how much articulatory phonetics as practiced in laboratory phonology has progressed with respect to the first attestations of instrumental phonetics, not only with reference to the dimension of technical possibilities, but also to theoretical awareness.

Competing Interests

The authors have no competing interests to declare.

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