A new artificial palate for tongue pressure measurements

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Electropalatography is a well-known technique for investigating tongue's movements during speech production. It is used for linguistics studies as well as in clinical therapy for language diseases.

During the last 50 years a lot of arrangements were tested and many different types of EPG palates were realized. The EPG Reading system is the most used both for linguistic and clinical purposes; it is composed by an artificial palate that is created from a customized cast and in which 62 electrodes are placed to ensure the recording of linguo-palatal contact. The system is able to capture the presence of the tongue contact in a specific area of the palate.

In the systems currently in use, there is no information in relation to the amount of pressure used for the realization of a specific contact; this value could be of interest for characterizing more in deep an articulation and could differentiate two gestures that are potentially equivalent in terms of amount of contact but not in term of strength.

In linguistics research, the possibility of adding the pressure information gives a more detailed description and creates a gradual description of the linguo-palatal gesture; in clinical studies too, the pressure measurement could be crucial for identifying specific disorders.

Some tentative EPG systems with new electrodes able to record pressure values were realized in the last years. In 1994 Matsumura et al. realized an EPG system with 5-force-sensor mounted palatal plate and used it in some clinical studies, but the limited numbers of sensors make it not largely applicable. In 2013 Sardini et al developed a wireless system with six pressure sensors; this model is a challenging prototype that has the advantage of having eliminated all the wires that cover the traditional EPG system. However, the limited number of electrodes doesn't allow to use it for research purpose; furthermore the equipment necessary for the wireless connection placed directly on the artificial palate reduces the space useful for linguistic characterizations.

In this presentation we want to describe an innovative EPG palate prototype based on the geometry of the Reading one, but with new sensors able to capture the information related the pressure. Its sensors are sensitive enough to cover the specific range of pressure exerted by the tongue on the palate. It overtakes the previous systems thanks to the presence of a great number of pressure sensors (62), positioned in specific anatomical points in order to quantify the amount of contact of the tongue on the entire palate. Moreover the new design has a reduced invasiveness for the speaker; it is thin and flexible to adapt comfortably to the palate. It is realized in a way that could have manufacturing processes at a lower cost respect to the current one.

The first objective of this research project is the right choice of the sensor technology that best suits the design specifications. In particular, general requirements are a size compatible with the Reading system and a thin, thick and flexible structure, to be comfortable to the subject and not introduce complaints; at the same time stability over time, so as to ensure subsequent use without loss of accuracy. Finally, it must have the ability to detect the pressure of the tongue on the palate within the whole range of interest.

The materials chosen for the realization of the sensors are the *smart textiles*, because tissues are fibrous materials characterized by a high ratio between length and thickness and they possess a significant change in a specific property, caused by an external agent, such as a pressure. Among these, the commercial fabric *EeonTex* (0.44 mm thickness and 1-10 KΩ / 100mm resistivity) was used because it has the peculiarity that it varies its transverse resistance under a loading action.

The single responsive unit (Figure 1) is composed by a dielectric central diameter of 25 mm and 0.15 mm thickness, with 1.4 mm central hole of the film compatible with the single sensitive units present on the Reading reference system and two-fabric outer layer piezo resistive EonTex with 15mm diameter.

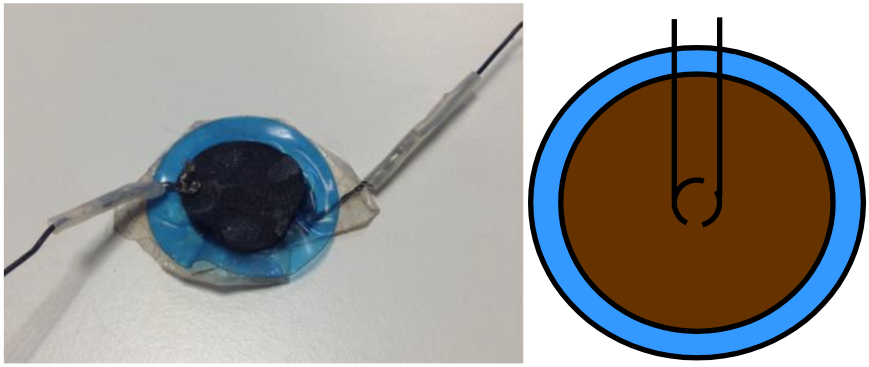

Fig 1: single unit

The technology traditionally used for the realization of matrix sensors and based on smart fabrics involves the use of three superimposed layers (Figure 2): a power supply layer composed of isolated conductive lines between them, a central layer of piezoresistive material and a reading layer composed of isolated conductive columns between them.

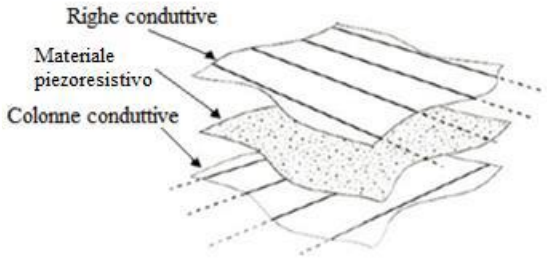

Fig2. Matrix sensor

The final prototype was realized (Fig.3) and then tested, thanks to a preliminary acquisition system that has been specifically developed and is able to record and process contact pressure data, giving a real-time visual feedback of the pressure exerted by the tongue on the various points of the palate.

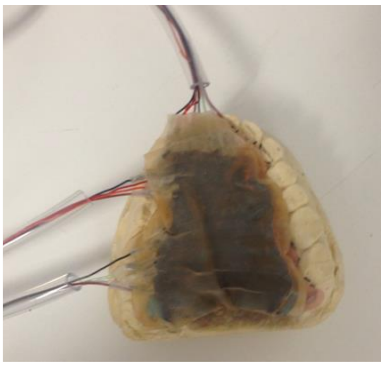

Fig. 3: Palate prototype

Specifically, a subject has performed preliminary tests pronouncing consonants included in /Ca/ syllables, to evaluate whether and how the system responds to different stresses of the tongue on the palate. Four consonants were pronounced ([t], [d], [n] and [l]). Figure 4 and 5 show the visual feedback that the pressure exerted by the tongue exhibits in real time. Overall contact pressure patterns (on the left) are compared to reference /t/ and /d/ contact patterns as attested in previous EPG literature.

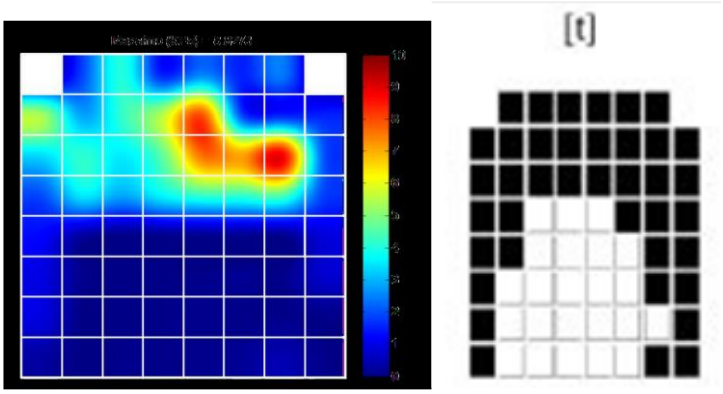

Fig 4: /t/

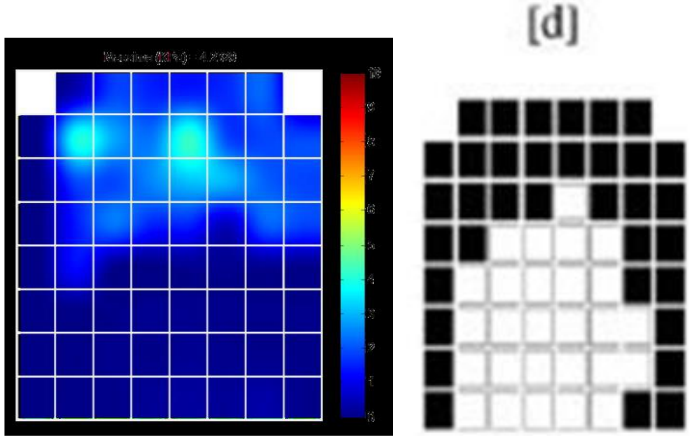

Fig 5: /d/

The conference contribution will also discuss some limitations of the proposed prototype, such as the positioning of the electrodes that still needs a higher level of details and the acquisition frequency that is currently lower than in the Reading system.

Given the large amount of anatomical and biomechanical detail currently implicated in contemporary phonetic and phonological reasoning, similar advances in EPG techniques are highly promising for the development of general theories of speech production as well.

In addition, the possible implications of similar prototypes for the development of general phonetic/phonological theory will be discussed. In particular, we believe that broad notions related to constriction location, magnitude of the gestural movement, apical vs. laminal contact in coronal consonants or articulatory force could largely benefit from contact pressure information.

In fact, characterizing the contact pressure patterns in lingual articulation will not only allow to make finer distinctions among contact patterns that are equivalent in space and different in pressure, but also to detect, within one and the same contact pattern, the areas of maximal and the areas of minimal linguo-palatal pressure. This in turn could prove useful for a better understanding of both spatial and temporal dynamics characterizing lingual movements, lingual targets, active vs. inertial displacements, sound changes rooted in production's characteristics.

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