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Biomechanical models of speech articulators to study speech motor control

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Visible and audible speech signals are the results of the movements of the vocal tract articulators. These articulators are made either of bones or of soft tissues. Thus, they have complex and variable biomechanical properties. In our research group, we believe that the influence of these biomechanical properties on the spatio-temporal patterning of speech signals is very important and that it has largely contributed to determine the physical characteristics that are relevant for the linguistic oral exchanges between speakers and listeners.

For this reason we have been working in the last 15 years on the development of increasingly complex and realistic biomechanical models of the tongue, the face and the mandible. All kinds of speech movements have been generated with these models controlled on a target-to-target basis. With such a motor control model, the trajectories, the velocity profiles and the actual amplitudes of the simulated movements are not directly specified by the Central Nervous System. They are the consequences of a combination of effects, namely those of the motor commands patterns and their timing, and those of the biomechanical characteristics of the articulators. Various comparisons of the kinematic properties of the simulated movements with those of real articulatory movements recorded from speakers of various languages (French, German, English and Mandarin Chinese) have been carried out. This methodology allowed us evaluating quantitatively the influence of biomechanics on speech movements, and clarifying which speech movement properties seem to require a specific control from the Central Nervous System and which properties could simply emerge from the physical characteristics of the speech production apparatus.

In this talk the methodology used to design our models will be shortly presented. Then, results obtained at different stages of our work, with different models, will be shown, which illustrate how these models can be used to better understand speech motor control. We will consider examples where biomechanics informs us about the trajectory shapes, the relations between velocity and trajectory shape, the relations between motor control accuracy and acoustic variability, and the influence of dynamical properties on the shaping of soft speech articulators.

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