Imagined speech influences perceived loudness of sound

With the support by the National Natural Science Foundation of China, the research team directed by Prof. Tian Xing (田兴) at New York University Shanghai, Shanghai Key Laboratory of Brain Functional Genomics (Ministry of Education), School of Psychology and Cognitive Science, East China Normal University, and NYU-ECNU Institute of Brain and Cognitive Science at NYU Shanghai, recently reported that imaged speaking can influence how loud we perceive sound, which was published in *Nature Human Behaviour* (2018, 2: 225—234).

How top-down and bottom-up processes interact to shape cognition is a fundamental question in psychology and cognitive neuroscience and remains highly controversial. For example, top-down signals from the motor system have been hypothesized to transfer to sensory systems for predicting the perceptual consequences of actions. This top-down motor-based prediction interacts with the bottom-up perceptual processing, and such interaction has been assumed to be the critical mechanism that mediates various cognitive functions, such as speech production and control. However, how early in a processing stream such interactions occur and what factors govern such interactions are still unknown. Tian et al. hypothesized that the abstractness levels of perceptual attributes (e. g. loudness versus sound identity in hearing) may determine the processing of interaction between bottom-up and top-down internal information.

The aim of this study is to manipulate the level of abstraction of a perceptual attribute and examine behaviorally and electrophysiologically whether we observe top-down modulation on perception. Tian's group carried out a series of experiments using a new imagery-perception adaptation paradigm to investigate whether top-down mental imagery affected auditory perception, even for a most basic auditory attribute such as loudness. They found that the 'internal loudness' of imagery affected the subsequent overt loudness judgment: participants rated the sound as softer when they imagined speaking loudly, and *vice versa*. Concurrently acquired magnetoencephalography (MEG) and electroencephalography (EEG) results were consistent with the behavioral findings, suggesting the neural processes associated with the imagery directly modulated the early neural responses to the overt auditory stimuli, which is the neural basis for the observed behavior.

Their results demonstrate that perception is a result of interaction between top-down and bottom-up processes. They not only passively receive and analyze external stimuli, but also actively manipulate and interpret these signals to form perception. Moreover, this study, as the latest piece of a series of studies conducted in their group using mental imagery paradigms to investigate speech monitoring and control [Tian & Poeppel, 2010; 2012; 2013; 2015; Tian, Zarate & Poeppel, 2016], further suggests that this top-down motor-based predictive process can even extend and predict the low-level auditory attribute such as loudness, enabling monitoring in all levels of speech hierarchy. The combination of top-down and button-up interaction mechanism and monitoring and control functions may implicate the potential mechanisms of mental disorders, especially auditory hallucination mostly in schizophrenia from a cognitive neuroscience perspective.

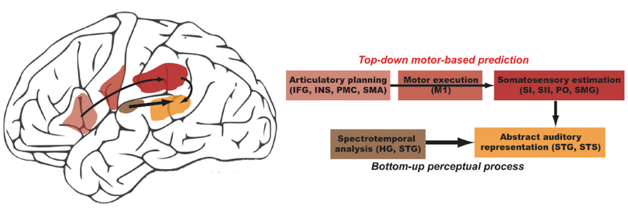

Figure Proposed model for the mechanism of interaction between top-down and button up processes. Top-down motor-based perceptual prediction can be generated by the signals sending from the motor system. Such prediction can interact with bottom-up perceptual process to establish our perception and other cognitive functions. Approximate cortical regions (Left) and schematic diagram (Right) of the mechanism (color scheme corresponds to the anatomical locations in the left plot). Abbreviations: HG, Heschl's gyrus; STG, superior temporal gyrus; STS, superior temporal sulcus; IFG, inferior frontal gyrus; PMC, premotor cortex; INS, insula; SMA, supplementary motor area; M1, primary motor cortex; PO, parietal operculum; SI and SII, primary and secondary somatosensory cortices; and SMG, supramarginal gyrus.