Stimulating speech: Auditory-motor interactions in production and perception

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I will describe a series of experiments employing non-invasive brain stimulation in combination with measures of brain function, which explore auditory-motor interactions during speech perception and speech production. Using transcranial magnetic stimulation (TMS), we and others showed that the excitability of the primary representation of the articulators in left motor cortex increases during speech perception (Watkins et al., 2003; Fadiga et al., 2003; Murakami et al., 2011). This increased excitability correlated with brain activity in a network of areas in the left hemisphere including the posterior part of the left inferior frontal cortex (Watkins et al., 2004). Virtual lesions to primary motor representations created using TMS can reduce categorical perception of speech sounds (Mottonen et al., 2009) indicating the importance of interactions between the motor and the auditory systems during speech perception. Using TMS and EEG, we showed that the motor cortex contributes to early stages of speech processing in the auditory cortex; virtual lesions to lip area reduce the mis-match negativity to speech sounds but not other auditory stimuli (Mottonen et al., 2013). Using TMS and MEG, we showed that these early effects can be fine-tuned by attention (Mottonen et al., 2014).

In a parallel set of studies, we have examined how stimulation of the motor system can enhance speech production abilities. Using functional imaging in people who stutter, we find that the activity in the primary motor representation of the articulators and primary auditory cortex is poorly synchronised during speech production but that altered auditory feedback can improve this coordinated activity and also improves speech fluency (Watkins et al., 2011). We used transcranial direct current stimulation (tDCS) to modulate the excitability of the motor cortex during speech production in people who stutter and fluent controls during speech motor learning. Five days of anodal tDCS over the speech motor cortex coupled with fluency training successfully improved speech production in people who stutter by reducing disfluencies (Chesters et al., 2018). In normally fluent controls, anodal tDCS to either the motor cortex or the cerebellum improved speech motor learning in terms of the adaptation to a perceived formant shift (Lametti et al., 2018).

Taken together these studies demonstrate the strength of brain stimulation methods. By combining brain stimulation with other measures one can temporarily interfere with brain function and subsequently read out the effects of this perturbation on behaviour or on other correlational measures acquired using brain imaging. Our work has confirmed the importance of interactions between motor and sensory systems that are necessary for both speech perception and production.

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