

Workshop

## **Stimulating speech: Auditory-motor interactions in production and perception**

K.E. Watkins, Dept. Experimental Psychology, University of Oxford

In my lab, we use non-invasive brain stimulation to explore auditory-motor interactions during speech perception and speech production. I will describe how transcranial magnetic stimulation (TMS) works and provide a number of examples of how we have used this method in combination with behaviour and other measures of brain function. This work started in Montreal, when 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). Temporary interference of primary motor representations 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. By combining TMS and EEG, we showed that the motor cortex contributes to early stages of speech processing in the auditory cortex (Mottonen et al., 2013). By combining 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 electrical stimulation of the motor system can enhance speech production abilities. We have 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 modulate 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.

### References

- Chesters J, Möttönen R, Watkins KE (2018) Transcranial direct current stimulation over left inferior frontal cortex improves speech fluency in adults who stutter. *Brain* 141(4): 1161-1171 doi: 10.1093/brain/awy011.
- Fadiga L, Fogassi L, Pavesi G, Rizzolatti G. (1995). Motor facilitation during action observation: A magnetic stimulation study. *Journal of Neurophysiology*, 73(6), 2608–2611.

- Lametti DR, Smith HJ, Freidin PF, Watkins KE (2018) Cortico-cerebellar Networks Drive Sensorimotor Learning in Speech. *J Cogn Neurosci*. 30(4):540-551. doi: 10.1162/jocn\_a\_01216.
- Möttönen R & Watkins KE (2009) Motor representations of articulators contribute to categorical perception of speech sounds. *J Neurosci* 29(31):9819-25.
- Möttönen R, Dutton R & Watkins KE (2013) Auditory-motor processing of speech sounds. *Cerebral Cortex* 23(5): 1190-1197.
- Mottonen R, van de Ven G, & Watkins KE (2014) Attention fine-tunes auditory-motor processing of speech sounds. *J Neuroscience*, 34(11): 4064-9.
- Murakami T, Restle J, Ziemann U. (2011). Observation–execution matching and action inhibition in human primary motor cortex during viewing of speech-related lip movements or listening to speech. *Neuropsychologia*, 49(7), 2045–2054.
- Watkins KE & Paus T (2004) Modulation of motor excitability during speech perception: the role of Broca's area. *Journal of Cognitive Neuroscience* 16(6): 978-987.
- Watkins KE, Strafella AP & Paus T (2003) Seeing and hearing speech excites the motor system involved in speech production. *Neuropsychologia* 41: 989-994.