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Transcranial Magnetic Stimulation Produces Speech Arrest but Not Song Arrest

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Transcranial magnetic stimulation (TMS) is a tool that can be used to disrupt cortical processing for a few tens of milliseconds and, when combined with cognitive paradigms, can be used to look at the role of specific brain regions. TMS can be described as a way of creating virtual neuropsychological patients, but can also extend these findings. It can be delivered focally in time and therefore has the advantage of being able to provide information about the time course of cortical events. In addition, because “virtual lesions” are transient, the interpretation of behavioral effects are not complicated by the functional recovery that results when a damaged brain re-organizes.

One of the more famous neuropsychological patients is Paul Broca’s patient from 1861, who came to be known as “Tan” because this was the only sound he could produce. Postmortem examination of his brain revealed a lesion to the left inferior frontal region, which subsequently became known as Broca’s area. Using direct electrical stimulation in subjects undergoing surgery for epilepsy, Penfield and Rasmussen¹ demonstrated that speech arrest could be elicited when stimulation was applied over the inferior frontal zone of the dominant hemisphere. This can be distinguished from the motor type of speech arrest elicited by stimulation over rolandic cortex of either hemisphere, which is associated with contralateral activation of the tongue and lip muscles. TMS should, in principle, be able to produce the same results as those seen with direct electrical stimulation; after all, TMS is merely an alternative way of inducing electrical current in the brain; it has the advantage of being painless and can be performed on normal subjects.

Recently, we attempted to reproduce Penfield’s results using TMS. Subjects were seated comfortably, and TMS was applied at 10 Hz for 1 s at 140% motor threshold while the subject counted briskly upward, from 1 to 10. TMS was applied over an area of left frontal cortex at an arbitrary point in their counting. In 6 out of 9 subjects, speech was disturbed. Occasionally, speech was stopped entirely; in other subjects it was slowed or the quality of speech was altered. EMG measurements from the contralateral orbicularis oris muscle confirmed that the speech arrest was nonmotor in origin. Such effects could not be produced by stimulation over the homologous area of the right hemisphere, in keeping with the findings from neuropsychological patients.

The relationship between speech deficits and melodic production deficits is not clear-cut. Some neuropsychological evidence suggests that the two are independent; for instance, Tan was reported to be able to sing “La Marseillaise.”² Similar findings have

been reported in aphasic patients with left frontal lesions.³⁻⁵ However, other reports that patients with left frontal lesions may present with impaired speech and singing^{6,7} support the idea that these two functions arise from the same brain area. Gordon and Bogen⁸ provide evidence that melodic production is a right hemisphere function; injection of sodium amylobarbitone into the right carotid artery produced deficient singing. In addition, Alexander et al.⁹ observed impaired singing following damage to the internal capsule of the nondominant hemisphere.

In the second part of our study we attempted to produce “song arrest” using TMS. First, TMS was applied over the left frontal region until speech arrest was elicited. The subject was then asked to sing or hum a familiar tune such as “Happy Birthday,” twice with TMS and twice without, over the same area at which speech arrest had been produced. The song produced was compared with and without TMS for quality of melody and clarity of words. The coil was systematically moved across many different locations of the left frontal lobe. The procedure was repeated over the right frontal lobe. None of the five subjects tested showed any flattening or loss of melody with stimulation applied anywhere over the left or right frontal lobe. Furthermore, despite all subjects’ showing disturbed speech when stimulation was given over a specific region of the left frontal lobe speech, when they sang with words, the clarity of the words was completely unaffected.

The finding that stimulation over a region of the left frontal lobe affects speech but not melody supports the idea that these two functions are subserved by different brain areas. The fact that production of words while singing was unaffected even when speech alone was disturbed is counterintuitive and suggests that there may be something special about word production while singing—perhaps the melodic context facilitates word production. Yamadori et al.³ found that 12 out of 21 of Broca’s aphasic patients produced good text words while singing. Stimulation over the right frontal lobe did not impair melodic production. Perhaps it is the case that while the speech generation site can be well localized, the circuitry underlying melodic production is more diffuse. Indeed, even though the neuropsychological literature points to the right hemisphere’s involvement, there is little consensus as to where in the right hemisphere it may reside. Another possibility is that melodic production may just be more robust than speech production and hence less susceptible to interference.

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