Editorial

Similarity of spatiotemporal dynamics of language-related ECoG high-gamma modulation in Japanese and English speakers

Task-related modulation of intracranial EEG power spectra has been shown to represent average population firing rate of cortical neuronal clusters in non-human primates, and blood-oxygen-level dependent responses in humans (Lachaux et al., 2007; Ray et al., 2008). In clinical studies, power modulation in 50–400 Hz band during language tasks, called high-gamma modulation (HGM), has been shown to classify naming sites determined by electrical cortical stimulation (ECS) with high specificity and high diagnostic odds ratio (Arya et al., 2018a). Until recently, the major focus of such clinical studies was to evaluate diagnostic performance of HGM for pre-surgical language mapping using comparisons with ECS mapping and post-operative neuropsychological outcomes (Arya et al., 2018a, 2019b, 2017, 2018b; Genetti et al., 2015; Kojima et al., 2012; Mooij et al., 2016; Sinai et al., 2005; Towle et al., 2008). However, there is a growing realization that intracranial EEG signals contain multidimensional data which can be analyzed to study spatiotemporal dynamics of neuronal processing related to various cognitive domains. In one previous study including 7 adults, different temporal envelopes for HGM in cortical language networks were seen, resulting in complex, cascading spatio-temporal patterns of activation (Wang et al., 2016). During object naming, HGM was first noted in basal temporal-occipital cortex (visual processing), followed by Broca's area and sensorimotor cortex (speech planning and preparation) (Wang et al., 2016). Another large study (n = 100, including 16 children <10 years of age), reported 70–110 Hz HGM during an auditory naming task in bilateral superior temporal gyri (STG) and precentral gyri immediately after question onset; in cortex overlying perisylvian language network in the left hemisphere and cingulate gyrus around question termination, and in bilateral posterior superior frontal, and peri-rolandic cortex, before verbal response (Nakai et al., 2017). However, studies on the diagnostic performance of HGM language mapping, as well as those on the spatiotemporal dynamics of brain-language interactions have been predominantly limited to native speakers of English (Arya et al., 2018a; Nakai et al., 2017; Wang et al., 2016).

In this issue of Clinical Neurophysiology, Ikegaya et al. describe spatiotemporal dynamics of HGM during auditory and picture naming tasks in 10 native Japanese speaking patients, undergoing extra-operative electrocorticography (ECoG) monitoring (Ikegaya et al., 2019). Authors found HGM specifically during auditory naming in bilateral STG (typically during sentence listening), and left perisylvian cortex; whereas HGM specific to picture naming was noted in bilateral fusiform gyri and surrounding occipital cortex. Additionally, the inferior peri-rolandic cortex was noted to show HGM associated with overt responses, during either task. Hence, this study demonstrated different pathways for processing different receptive linguistic stimuli according to the sensory modality, which converged onto a common expressive locus. These observations are fairly similar to those published by authors' group and others in native English speaking patients, as mentioned above (Nakai et al., 2017; Wang et al., 2016). Hence, it can be speculated that irrespective of the primary language, the underlying brain networks are essentially analogous, at least at the spatiotemporal resolution offered by conventional ECoG. The authors' proposal that this observation may pave the way for collaborative studies of brain language networks including speakers of different languages is well-founded, though it must await confirmation from further studies including patients who are native speakers of other languages with different syntax and structure, and also multi-lingual patients who have acquired different languages at different times in their lives.

The study by Ikegaya et al. is important in looking at the spatiotemporal dynamics in patients who exclusively spoke Japanese. In previous studies of HGM language topography in Dutch, French, German, and Japanese speaking patients, the signal processing was mostly configured to average over the entire trial epoch to facilitate comparison with the static ECS language maps (Bauer et al., 2013; Genetti et al., 2015; Mooij et al., 2016; Ogawa et al., 2017; Ruescher et al., 2013; Tamura et al., 2016). Hence, this study opens up a number of clinically relevant issues to be considered for future work in this area. Although intracranial EEG can inform spatiotemporal dynamics of functional brain networks, the best way to integrate this information in clinical practice is presently unclear. Resection of HGM language sites, which were ECS negative, has been shown to be associated with working memory deficits (Arya et al., 2019b). It is expected, but presently unproven, that incorporating spatiotemporal propagation of language-related HGM may further improve prediction of post-operative outcomes, making a case for incorporating dynamic spatiotemporal information for neurosurgical decisions. Such studies also help validate brain models of language function derived from lesion studies, functional neuroimaging, or neuropsychological data (Hickok, 2014; Hickok and Poeppel, 2007; Price, 2000). The incorporation of brain networks underlying proficiency in languages with

different syntax, or multilingualism, in these models remains to be achieved. So far, studies have described the temporal dynamics of spatial propagation of HGM during averaged trial(s) of a language task (Ikegaya et al., 2019; Nakai et al., 2017; Wang et al., 2016). Perhaps, the next frontier will be to incorporate analysis of information sharing, statistical causality, and dynamic connectivity, to better elucidate not just the anatomic areas involved over the time-course of a language stimulus-response, but the subnetworks which may be shared across different cognitive functional domains and thus define functional units of brain networks (Arya et al., 2019a; Collard et al., 2016). The ultimate goal will be to understand the age-related development of functional brain networks and the underlying mechanisms for information transfer within those networks, along with their interaction with an evolving epileptic process incorporating the etiology and course of epileptogenesis.

Disclosure

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