Broca’s area is not the speech output region

Sir,

We thank Dr Wu and colleagues for their interest in our recent probabilistic map of critical functional regions of the human cerebral cortex (Tate et al., 2014). In particular, we are pleased to note that in their experience with 69 Chinese-speaking patients the authors confirmed a 79% probability of anarthria/speech arrest with stimulation of the left ventral premotor cortex (PMC), similar to our results (83%). These data support the crucial role of the ventral PMC for speech output, as suggested in previous reports (Duffau et al., 2003; van Geemen et al., 2014).

Nonetheless, they also found a probability of ‘speech arrest’ in 32% of patients within the left pars opercularis (i.e. Broca’s area), which they stated is similar to the 26.7% rate observed by Sanai et al. (2008). However, if one looks at the primary data from the report by Sanai et al. (2008), which uses a relatively arbitrary 1 x 1 cm grid system, which does not specifically respect anatomic (sulci, gyri) or cytoarchitectural (Brodmann area) cortical features, there are three grids that include a portion of pars opercularis: for the two grids that are completely contained within pars opercularis, one has 0% speech arrest and another has 4.9%—these data are similar to our reported 4%. A third grid location has a reported 26.7% speech arrest rate (referred to in the letter by Wu and colleagues), but this region spans both pars opercularis and ventral PMC, so it is possible that many of the speech arrest sites are within the ventral PMC and not pars opercularis. In fact, in our study, there is a high density of speech arrest sites just posterior to the precentral sulcus, immediately behind the superior pars opercularis, but within ventral PMC (Tate et al., 2014). In addition, a recent study examining language deficits in glioma patients demonstrated that gliomas involving the ventral PMC were 5-fold more likely to cause aphasia compared to gliomas involving the inferior frontal gyrus (Bizzi et al., 2012), which also points to the ventral PMC as the primary speech output region. Another potential source for the discrepancy among studies evaluating speech arrest and anomias is related to the specifics of the chosen intraoperative tasks. For example, in our study, during the picture naming paradigm, patients are asked to proceed the object name with ‘This is a...’, enabling distinction of true anomia (where the patient will say ‘This is a...’ and cannot produce the object name) from speech arrest (patient is shown the picture and has zero verbal output). If one simply asked the patient to name pictures, it would be difficult to discern speech arrest from anomia. Thus, when reporting anomia, speech arrest, and articulation outcomes, it is important to precisely specify the intraoperative tasks employed to enable direct comparisons. Finally, as stated by Wu et al. (2014)
alphabetic languages (such as French and English) differ from pictographic languages (such as Chinese) in many aspects. However, it is nonetheless remarkable to note that, despite this difference, the actual area of speech output was the ventral PMC, independently of the language class, which strongly supports our theory.

Regarding the subcortical connectivity underlying speech articulation, it is crucial to distinguish the arcuate fascicle and the lateral part of the superior longitudinal fascicle (SLF). Indeed, by combining anatomic dissection and tractography, we have recently demonstrated that the arcuate fascicle primarily connected the posterior portion of the inferior and middle frontal gyri (and partly the ventral PMC) with the middle and inferior temporal gyri, whereas the anterior segment of the longitudinal SLF connected the ventral PMC with the supramarginal gyrus and superior temporal gyrus (Martino et al., 2013). First, this means that Broca’s area in not directly connected with Wernicke’s area, a notion already suggested by the traditional view of language processing, and allowing the proposal of new models of language connectivity (Duffau et al., 2014). Second, stimulation of longitudinal SLF generates articulatory disturbances, confirming the crucial role of the ventral PMC (i.e. the anterior cortical epicentre of this articulatory loop) in speech output (Maldonado et al., 2011; van Geemen et al., 2014). Third, stimulation of the arcuate fascicle does not elicit articulatory disorders, but phonemic disturbances (possibly associated with repetition errors) (Maldonado et al., 2011; Moritz-Gasser and Duffau, 2013), supporting the role of the pars opercularis (i.e. the anterior cortical epicentre of this dorsal pathway) in phonology (Duffau et al., 2002). In the same vein, recent data about the connectivity underpinning the left inferior frontal gyrus suggest a role for this area in high-order cognitive functions, such as verbal and non-verbal semantic processing (Broca’s area being one of the anterior cortical terminations of the ventral semantic stream subserved by the inferior fronto-occipital fascicle) (Duffau et al., 2005; Moritz-Gasser et al., 2013) as well as speech control (Broca’s area being a cortical termination of the frontal aslant tract) (Kinoshita et al., 2014) or even mentalizing (partly subserved by the arcuate fascicle) (Herbet et al., 2014a, b).

Finally, we acknowledge that slow-growing lesions such as low-grade gliomas may induce functional reorganization (Duffau, 2005). However, if we admit that neuroplasticity enabled the compensation of all areas involved by the tumour, it would not be possible to identify crucial epicentres in a probabilistic map based on glioma patients. Thus, the ability to detect critical epicentres with a high-rate of probability by inducing a reproducible deficit during intraoperative stimulation (such as anarthria during stimulation of the ventral PMC), despite cerebral reshaping, has significant implications for understanding the normal functional anatomy of the brain (Duffau, 2011). In fact, the crucial cortical language (phonemic, semantic) epicentres detected by intraoperative electrical mapping in the current study involving glioma patients (Tate et al., 2014) correlate well with results provided by functional MRI, extensively described in a meta-analysis extracted from 129 scientific reports (with 730 activation peaks) that investigated language using functional neuroimaging in healthy volunteers (Vigneau et al., 2006). In the same vein, we have recently demonstrated that specific critical structures, both at cortical level (e.g. the ventral PMC) and at subcortical level (e.g. the longitudinal SLF) (van Geemen et al., 2014) have a very low plastic potential (Duffau, 2013), leading to the concept of ‘minimal common brain’ (Ius et al., 2012).

References


