LETTER TO THE EDITOR

Subcortical damage and white matter disconnection associated with non-fluent speech

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Sir, In a recent paper published in *Brain*, Dronkers and colleagues (2007) re-examined the brain damage in two historic patients of P. Paul Broca, Leborgne and Lelong, who had lost the ability to speak following brain damage. The observation of these cases lead Broca to suggest that the left inferior frontal lobe (later coined Broca’s area) is the crucial lesion location associated with acquired motor speech impairment.

Utilizing high resolution MRI, Dronkers and colleagues observed that the brain damage in both of Broca’s cases extend further subcortically than Broca could have observed, therefore, suggesting that the critical lesion location for motor speech production is not restricted to the inferior frontal gyrus. In particular, the authors demonstrated that the superior longitudinal fasciculus was damaged in both cases, arguing that this lesion may also have affected Broca’s patients’ speech production.

This timely examination by Dronkers et al. combines a historical perspective and the current debate regarding the critical lesion location associated with non-fluent speech. In an earlier study employing lesion mapping in chronic stroke patients, Dronkers (1996) suggested that damage to the left anterior insula, but not to Broca’s area, is the crucial lesion location associated with non-fluent speech. Until then, Broca’s initial findings were largely undisputed by tangible evidence. These observations, however, were contrasted in a controlled study by Hillis and colleagues (2004) which investigated acute patients and observed that, indeed, Broca’s area, as opposed to left anterior insular damage, is strongly associated with non-fluent speech. In support of these findings, numerous studies utilizing functional MRI in normal participants have demonstrated a strong relationship between Broca’s area activity and speech production (Bonilha et al., 2006; Ozdemir et al., 2006; Guenther et al., 2006). For example, our group showed that the contrast between speech and non-speech oral movements revealed Broca’s area activity associated with speech movements but left anterior insula activity related to non-speech oral movements. Moreover, transcranial magnetic stimulation of the posterior portion of Broca’s area (i.e. pars opercularis) reliably interrupts speech production (Devlin and Watkins, 2007). How can these seemingly paradoxical findings be reconciled? In our opinion, these findings are not necessarily in conflict but, instead, provide complementary evidence regarding acquired non-fluent speech. In particular, these observations indicate that the integrity of the connections between the primary language areas are crucial for speech processing and production. Recently, our group showed that severing of the arcuate fasciculus with complete cortical sparing results in severe non-fluent aphasia (Fridriksson et al., 2007). We therefore suggest that subcortical damage, in particular involving insular lesions, leads to essential damage to fibre pathways conveying information for speech production (Ay et al., 2008). In order to examine this hypothesis, we performed a probabilistic tractography analysis of high-resolution diffusion tensor imaging (single shot EPI with voxels of $2 \times 2 \times 3$ mm, employing 12 diffusion directions with $b$-value of $1000 \text{s/mm}^2$, $\text{TR} = 6000 \text{ms, TE} = 90 \text{ms, matrix size} = 128 \times 128$) from 51 normal participants. We assessed the probabilistic pathway of the fibres travelling from the left Brodmann area (BA) 22 to left BA 45 on each individual using FMRIB’s Diffusion Toolbox—FDT v2.0 (http://www.fmrib.ox.ac.uk/fsl/fdt/index.html). The results were transformed into stereotaxic space and averaged onto a normal brain template. These results are displayed in Fig. 1, where it is evident that these pathways funnel immediately below the gray matter surface of the insula. Therefore, insular damage may lead to acquired non-fluent speech not because of gray matter damage but, instead, because of disconnection between posterior and anterior speech areas. In fact, Dronkers et al. in study in Brain demonstrate that Leborgne brain’s showed cortical insular damage, while Lelong’s
brain did not. Functionally, the feedback role of the posterior language areas in speech production has been extensively demonstrated by Guenther et al. (2006).

In conclusion, in accordance with Dronkers et al. findings, we suggest that Broca’s area is crucial for speech production, while its disconnection (e.g. at the level of the anterior insula) from the posterior language areas may also result in non-fluent speech. The integrity of the insular white matter and of the connections between the superior temporal cortex and the inferior frontal area is crucial for speech production.

References


Figure 1 This figure shows the anatomical location of reconstructed white matter pathways travelling from BA 22 to BA 45. The scale bar represents the overlap among tracts among the subjects. Fibre pathways are overlaid onto multi slices as well as a transparent 3D reconstruction of a normal brain template.