Does the left inferior longitudinal fasciculus play a role in language? A brain stimulation study

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Although advances in diffusion tensor imaging have enabled us to better study the anatomy of the inferior longitudinal fasciculus (ILF), its function remains poorly understood. Recently, it was suggested that the subcortical network subserving the language semantics could be constituted, in parallel with the inferior occipitofrontal fasciculus, by the left ILF, joining the posterior occipitotemporal regions to the temporal pole, then relayed by the uncinate fasciculus connecting the anterior temporal pole to the frontobasal areas. Nevertheless, this hypothesis was solely based on neurofunctional imaging, allowing a cortical mapping but with no anatomo-functional information regarding the white matter. Here, we report a series of 12 patients operated on under local anaesthesia for a cerebral low-grade glioma located within the left temporal lobe. Before and during resection, we used the method of intraoperative direct electrostimulation, enabling us to perform accurate and reliable anatomo-functional correlations both at cortical and subcortical levels. In order to map the ILF, using postoperative MRI, we correlated these functional findings with the anatomical locations of the sites where language disturbances were elicited by stimulations, both at cortical and subcortical levels. Our goal was to study the potential existence of parallel and distributed language networks crossing the left dominant temporal lobe, subserved by distinct subcortical pathways—namely the inferior occipitofrontal fasciculus and the ILF. Intraoperative stimulation of the anterior and middle temporal cortex elicited anoma in four patients. At the subcortical level, semantic paraphasia were induced in seven patients during stimulation of the inferior occipitofrontal fasciculus, and phonological paraphasia was generated in seven patients by stimulating the arcuate fasciculus. Interestingly, subcortical stimulation never elicited any language disturbances when performed at the level of the ILF. In addition, following a transient postoperative language deficit, all patients recovered, despite the resection of at least one part of the ILF, as confirmed by control MRI. On the basis of these results, we suggest that the “semantic ventral stream” could be constituted by at least two parallel pathways within the left dominant temporal lobe: (i) a direct pathway, the inferior occipitofrontal fasciculus, that connects the posterior temporal areas and the orbitofrontal region, crucial for language semantic processing, since it elicits semantic paraphasia when stimulated; (ii) and also possibly an indirect pathway subserved by the ILF, not indispensable for language, since it can be compensated both during stimulation and after resection.

Keywords: language; inferior longitudinal fasciculus; direct electrical stimulation; connectivity; brain mapping

Abbreviations: AMTLA = anterior and middle temporal language areas; ILF = inferior longitudinal fasciculus; DES = direct electrical stimulations

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Introduction

Although lesonal studies as well as neurofunctional imaging (for a meta-analysis, see Vigneau et al., 2006) have allowed a better knowledge of the cortical anatomo-functional organization of language, the subcortical white matter pathways have received less attention. Interestingly, the recent development of diffusion tensor imaging has enabled to perform a non-invasive tractography of the main bundles underlying language networks, and especially to
detail the different subcomponents of the superior longitudinal fasciculus, i.e. the ‘dorsal stream’ (Catani et al., 2005; Makris et al., 2005). However, this method enables to describe the sole anatomy of the pathways, but not of their function. Moreover, the ‘ventral stream’, while described in some DTI reports (Parker et al., 2005), is still poorly understood.

Yet, in 1993, Mazoyer et al. have shown using PETscan the involvement of the left temporal pole in language, in particular in semantic processing, in addition to the well-known posterior basitemporal areas (Devlin, 2003; Gaillard et al., 2006). In a recent study, the same team has suggested that the network subserving the language semantics could be constituted, in parallel with the inferior occipitofrontal fasciculus (Duffau et al., 2002, 2005), by the left inferior longitudinal fasciculus (ILF), joining the posterior occipitotemporal regions to the temporal pole, then relayed by the uncinate fasciculus connecting the anterior temporal pole to the frontobasal areas (Vigneau et al., 2005). Nevertheless, this hypothesis was solely based on neurofunctional imaging works, allowing a cortical mapping but with no anatomofunctional information regarding the white matter. In the same period, Catani et al. used the DTI technique to track the ILF, a pathway supposed to subserve direct occipito-temporal projections, while still matter of debate (Tusa and Ungerleider, 1985; Kier et al., 2006). Again, this study was able to give only anatomical data, with no functional information.

As a consequence, in the present article, we used the method of intraoperative direct electrostimulation, extensively reported by the authors as able to perform accurate and reliable anatomo-functional correlations both at cortical and subcortical levels (Duffau et al., 2002, 2005), in order to map the ILF in patients operated on awake for a tumour involving the left dominant temporal lobe. This study is therefore a complement of a previous work we published using the same technique, which demonstrated the role of the inferior occipitofrontal fasciculus in semantic language processing (Duffau et al., 2005). Here, our goal was to study the potential existence of parallel and distributed language networks crossing the left dominant temporal lobe, underlain by distinct subcortical pathways—namely the inferior occipitofrontal fasciculus and the ILF.

**Material and methods**

**Subjects**

Among a series of 200 patients operated on in our institution between 1996 and 2005 for a WHO grade II glioma located within eloquent areas using intraoperative electrical mapping, we have selected patients harbouring a tumour within the left dominant hemisphere and who underwent awake surgery in order to identify and preserve the language areas during resection.

Preoperatively, all patients have had a neurological examination. Language was tested by a speech therapist using the Boston Diagnostic Aphasia Examination (BDAE) (Goodglass and Kaplan, 1972). Handedness was assessed using a standardized questionnaire (Edinburgh inventory) (Oldfield, 1971). Hemispheric language dominance was determined by fMRI, using a protocol previously reported (Lehericy et al., 2000).

The topography of the tumour was accurately analysed on a preoperative MR image (T1-weighted and spoiled-gradient images obtained before and after gadolinium enhancement in the three orthogonal planes, and T2-weighted axial images).

**Intraoperative mapping**

All patients underwent awake surgery under local anaesthesia so that functional, especially language, cortical and subcortical mapping could be carried out using direct electrical stimulations (DES). This method, including the electrical parameters and the intraoperative clinical tasks, was described previously by the authors (Duffau et al., 2002, 2003, 2005). A bipolar electrode with 5 mm spaced tips delivering a biphasic current (pulse frequency of 60 Hz, single pulse phase duration of 1 ms, amplitude from 2 to 8 mA) (Ojemann Cortical Stimulator 1, Radironics, Inc., Burlington, MA, USA) was applied to the brain of awake patients.

In first stage, cortical mapping was performed, after tumour and sulci/gyri identifications using ultrasonography, and before resection, in order to avoid any eloquent area damage. Sensorimotor mapping was performed first, to confirm a positive response (e.g. the induction of movement and/or paraesthesia in the contralateral hemibody when the primary sensorimotor areas were stimulated in a patient at rest), since the boneflap allowed good exposure of the central region in all patients. Under local anaesthesia, the current intensity adapted to each patient was determined by progressively increasing the amplitude from 1 to 1 mA, from a baseline of 2 mA, until a sensorimotor response was elicited, with 8 mA as the upper limit, with the goal of avoiding the generation of seizures. Then, the patient was asked to perform counting (regularly from 1 to 10 over and over) and picture naming (preceeded by a short sentence to read, namely the French translation of ‘this is a . . .’, in order to check that there were no seizures generating complete speech arrest if the patient was not able to name), that is the two tasks most often reported during intraoperative functional mapping—in order to identify the essential cortical language sites known to be inhibited by stimulations (Ojemann et al., 1989; Duffau et al., 2002, 2003, 2005). For the naming task, we used the DO 80, which consists of 80 black and white pictures selected according to variables such as frequency, familiarity, age of acquisition and level of education (Metz-Lutz et al., 1991). These stimuli are homogeneous along the different categories, with normative data (Metz-Lutz et al., 1991).

The patient was never informed when the brain was stimulated. The duration of each stimulation was 4 s. At least one picture presentation without stimulation separated each stimulation, and no site was stimulated twice in succession, to avoid seizures. Each cortical site (size 5 mm × 5 mm, due to the spatial resolution of the probe) of the entire cortex exposed by the boneflap was tested three times. Indeed, it is nowadays admitted since the publication princeps of Ojemann et al. (1989) that three trials are sufficient to assure if a cortical site is essential or not for language—e.g. generating speech disturbances during its three stimulations, with normalization of language as soon as the stimulation is stopped. This limitation of trials and tasks is
required by the timing of the surgical procedure, since the patient is awake.

The type of language disturbances was detailed by a speech therapist systematically present in the operative room during the functional mapping. Items not correctly named preoperatively were excluded for the preoperative testing. Each eloquent area was marked using a sterile number tag on the brain surface, and its location correlated to the anatomical landmarks (sulci/gyri/tumour boundaries) previously identified by ultrasonography. A photograph of the cortical map was systematically made before resection.

During a second surgical stage, the glioma was removed, by alternating resection and subcortical stimulations. The functional pathways were followed progressively from the cortical eloquent sites already mapped, to the depth of the resection. The patient had to continue to count and/or name when the resection became close to the subcortical language structures, which were also identified by language inhibition during stimulations as at the cortical level (Skirboll et al., 1996; Duffau et al., 2002, 2003, 2005). Again, the type of language disturbances was detailed by a speech therapist all along the resection. In order to perform the best possible tumour removal with preservation of the functional areas, all the resections were pursued until eloquent pathways were encountered around the surgical cavity. Thus, there was no margin left around the cortico-subcortical eloquent areas. As for the cortical sites, each subcortical pathway is causally identified by repeated stimulations along 2–3 cm of fasciculus.

Postoperative functional outcome was assessed systematically by the same neurosurgeons and speech therapist as preoperatively, using the same tasks as preoperatively, both during the immediate postoperative stage and 3 months after surgery.

A control MRI was performed in all cases, immediately and 3 months after surgery. This imaging allowed first to evaluate the quality of glioma removal, and secondly to analyse the anatomical location of the language pathways—i.e. at the periphery of the cavity, where the resection was stopped, a methodology that we previously used (Duffau et al., 2002, 2003, 2005). In addition, we systematically evaluated on postoperative MRI if the cortical resections included the four areas of the anterior and middle temporal lobe involved in language which have been described in a recent fMRI meta-analysis (Vigneau et al., 2006): the temporal pole (TP), the anterior part of the superior temporal gyrus (T1a), the middle part of the middle temporal gyrus (T2m), and the anterior part of the fusiform gyrus (Fusa).

Results

The clinical, radiological and surgical characteristics of the 12 patients are summarized in Table 1.

Subjects

Twelve patients fulfilled the inclusion criteria. The series consisted of eight males and four females, ranging in age

### Table 1 Clinical, radiological and surgical characteristics of the 12 patients operated on for a WHO grade II glioma in the left dominant hemisphere, using intraoperative language mapping

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age</th>
<th>Handedness</th>
<th>Seizures</th>
<th>Language examination</th>
<th>Localization</th>
<th>AMTLA stim</th>
<th>Resection</th>
<th>SC-fasciculus</th>
<th>Transient (&lt;8 days) postoperative deficit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>38</td>
<td>R</td>
<td>G</td>
<td>T2, T3, T4</td>
<td>T2m</td>
<td>Fusa</td>
<td>A/IOF</td>
<td>Fluency</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>50</td>
<td>R</td>
<td>G</td>
<td>T2, T3, T4</td>
<td>T1a</td>
<td>TP, T2m,</td>
<td>A/IOF/OR</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>26</td>
<td>R</td>
<td>No (intracranial hypertension)</td>
<td>T2, T3, T4, T5</td>
<td>T2, T3, T4</td>
<td>T1a, T2m,</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>39</td>
<td>R</td>
<td>G</td>
<td>T2, T3, T4, T5 (middle &amp; post)</td>
<td>T2, T3, T4, T5</td>
<td>T1m</td>
<td>TP, T2m, Fusa</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>27</td>
<td>R</td>
<td>G</td>
<td>T5</td>
<td>T1a</td>
<td>TP, T1a, T2m, Fusa</td>
<td>A/IOF/Naming</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>36</td>
<td>L</td>
<td>G</td>
<td>T4, T5, T1a</td>
<td>TP, T2m, Fusa, A</td>
<td>A/IOF/Naming</td>
<td></td>
<td></td>
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<tr>
<td>7</td>
<td>F</td>
<td>39</td>
<td>R</td>
<td>P</td>
<td>T2, T3, T4, T5</td>
<td>T1a, T2m, Fusa</td>
<td>IOF/OR</td>
<td>Naming</td>
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<tr>
<td>8</td>
<td>M</td>
<td>34</td>
<td>R</td>
<td>G</td>
<td>T2, T3, T4, T5 (middle &amp; post)</td>
<td>T2, T3, T4</td>
<td>T2m</td>
<td>Fusa</td>
<td>IOF/A</td>
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<tr>
<td>9</td>
<td>F</td>
<td>36</td>
<td>R</td>
<td>P</td>
<td>T2, T3, T4, T5</td>
<td>T2m</td>
<td>Fusa</td>
<td>IOF/A</td>
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<tr>
<td>10</td>
<td>M</td>
<td>33</td>
<td>R</td>
<td>G</td>
<td>T2, T3, T4, T5</td>
<td>T2m</td>
<td>Fusa</td>
<td>IOF/A</td>
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</tr>
<tr>
<td>11</td>
<td>M</td>
<td>26</td>
<td>R</td>
<td>P</td>
<td>T1, T2m</td>
<td>Tla</td>
<td>T2m</td>
<td>IOF</td>
<td>Naming</td>
</tr>
<tr>
<td>12</td>
<td>F</td>
<td>17</td>
<td>R</td>
<td>G</td>
<td>T2</td>
<td>T2m</td>
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</tbody>
</table>

M = male; F = female; R = right; L = left; G = generalized; P = partial; AMTLA stim = AMTLA identified by stimulations; SC-fasciculus = subcortical fasciculus identified by stimulations; TP = temporal pole; Fusa = anterior fusiform gyrus; A = arcuate fasciculus; IOF = inferior occipitofrontal fasciculus; OR = optic radiations; Post = posterior.
from 17 to 50 years (mean 33 years). All patients but one were right-handed as assessed by the Edinburgh inventory; left hemisphere language dominance was established for each patient by preoperative fMRI.

The presenting symptoms were seizures in 11 cases (eight generalized, three partial with transient language disturbances).

The preoperative neurological clinical testing was normal in all patients. However, while language examination could also be considered within a ‘normal range’ using the BDAE in six cases, the six other patients did not succeed to obtain the maximum score, demonstrating that language disturbances were already present.

The preoperative MRI showed in all cases a T1-weighted hypointense and T2-weighted hyperintense left temporal lesion, without enhancement after gadolinium injection.

Middle temporal gyrus (T2), inferior temporal gyrus (T3) and anterior (as well as posterior in two cases) fusiform gyrus (T4) were invaded in seven patients (Fig. 1) with further involvement of the parahippocampic gyrus, hippocampus and amygdala (T5) in four patients among them. In addition, one patient had a tumour located exclusively in T1, one in T2, one in T5, one in T4–T5 and one in the temporal pole—also involving the insula.

At the end of this presurgical clinico-radiological evaluation, due to the location of the tumour within the left dominant hemisphere, we decided to perform an awake surgery in all patients. The aim was to benefit from an intraoperative electrical language mapping, in order to check objectively the actual presence (or not) of essential language sites within the left hemisphere both at cortical and subcortical levels, and to preserve them if detected—then to minimize the risk of postsurgical permanent aphasia.

Operative findings

At the cortical level, after identification of the well-known inferior frontal and/or posterior temporal areas, anterior and middle temporal language areas (AMTLA) were also tested. Intraoperative stimulation of the temporal lobe elicited anomia for two patients when performed in T2m, and for two other patients when performed in T1a (Fig. 2). No other language disturbance was induced by anterior and middle temporal cortex stimulation.

At the subcortical level, stimulation elicited semantic paraphasias in seven patients, when applied on the white bundle located under the superior temporal sulcus, just above the roof of the temporal horn of the ventricle. When stimulation was performed more posteriorly and superiorly in the deep part of the cavity in seven patients, namely at the level of the temporal part of the arcuate fasciculus, phonological paraphasias were induced. Moreover, for two patients, phosphenes were elicited in the inferior visual field, due to stimulation of the optic radiations. Interestingly, subcortical stimulation never elicited any language disturbances when performed laterally and inferiorly to the wall of temporal horn of the ventricle, and it was thus possible to continue the resection until the opening of the lateral horn of the ventricle.
Postoperative course

Postoperatively, a severe transient language deficit was noted in five patients, with naming disturbances in four cases and decrease of fluency in one case.

All patients benefited from speech rehabilitation, which allowed a complete functional recovery systematically evaluated using the same BDAE as preoperatively, and showing a normalization of the scores. It is worth noting that this rehabilitation was rapid, intensive and specific, i.e. with a beginning in the 10 days following the resection, at least 4 or 5 times per week, and adapted to the deficit—for instance, more focused on semantic rehabilitation in cases of semantic disorders (four patients), or more focused on phonological rehabilitation in cases of phonological disorders (one patient). All patients returned to a normal socio-professional life.

Histological examination revealed glioma grade WHO II in all cases.

Radiological results

According to the recent fMRI meta-analysis (Vigneau et al., 2006) showing the existence of four cortical areas within the anterior and middle temporal lobe participating in language, our resections involved the TP in seven patients, T1a in five patients, T2m in five patients and Fusa in nine patients (Fig. 1).

At the subcortical level, postoperative MRI confirmed that at least one part of the ILF was resected in all patients but one (the patient with a tumour located within T1), since the tumour removal involved systematic opening of the inferior and lateral part of the temporal horn of the ventricle.

Discussion

To our knowledge, this is the first report which has tried to study the possible involvement of the ILF in language, by direct and transient inhibition using intraoperative subcortical stimulation in awake patients.

Anterior and middle temporal language area

Before discussing the function of this pathway, it seems important first to consider the role of the cortical AMTLA. Indeed, while the involvement of the posterior temporal areas in language is well-known since the seminal work of Wernicke, less data are available regarding the AMTLA. Functional non-invasive studies in healthy volunteers have evidenced that the anterior and middle left (dominant) temporal lobe are involved in language networks. Four cortical sites in this region have been statistically defined by a recent meta-analysis (Vigneau et al., 2006): T1a, T2m, TP and Fusa. T1a and T2m are activated by phonological, semantic and sentence-processing tasks. The temporal pole seems to be involved in syntactic processing, especially the encoding and retrieval of complex linguistic material from long-term memory. The anterior fusiform gyrus could be a word–concept node (Gold et al., 2006), where the meaning of a word can be directly accessed (whatever the modality of presentation, including reading or auditory listening).

It is worth noting that these findings are more or less coherent with the practical knowledge of neurosurgeons. It is indeed the classical view to preserve T1a and T2m in a temporal lobectomy. However, it is usual to perform the resection of the TP and the Fusa, without severe postoperative language deficit (at least at neurological examination).

In the present series, these areas have been tested intraoperatively for naming, except the Fusa (due to its difficult access and because of the pain induced by proximity of the basal dura mater). Anomia has been elicited for two patients in the T1a and for two other patients in the T2m. These results confirm the participation of these sites in language function. For these four patients, the responding regions have not been resected. Nevertheless, the resection of these sites in the other patients (as well as the TP in seven cases and Fusa in nine cases) did not induce definitive deficit. The main hypothesis is that AMTLA might be particularly subject to preoperative plasticity induced by slow-growing low-grade glioma (Duffau et al., 2005). In other words, even if involved in language, these areas can be functionally compensated, since no deficit was observed on postsurgical BDAE despite their resection. This result is also supported by the extensive literature in epilepsy surgery (Ojemann et al., 2003). Resection of the anterior temporal lobe or Fusa can lead to immediate postoperative language deficits, but this deficit usually recovers within 6 months to 1 year (Luders et al., 1991; Langfitt and Rausch, 1996). The mechanisms underlying re-organization during recovery are under investigations by PET and MEG studies (Grabowski et al., 2003; Pataria et al., 2005).

ILF and language

Together with sites in the angular gyrus and the orbital part of the inferior frontal gyrus, it was recently hypothesized that TP and Fusa could be a part of a semantic network, that might be underlain by the ILF, also called occipito-temporal fasciculus (that links the posterior areas to the TP) then relayed by the uncinate fasciculus (that connects the TP to the orbitofrontal areas) (Vigneau et al., 2006).

ILF was first described by K. F. Burdach (Pollyak, 1957) in 1822, then by J. Déjerine in 1895 with Weigert-stained 2D atlas. The Klinger methods allowed the 3D description of the ILF (Ludwig and Klinger, 1956). This tract connects the occipital lobe with the anterior part of the temporal lobe, running laterally and inferiorly to the lateral wall of the temporal horn. It is located just laterally and under the optic pathways, whereas the inferior occipitofrontal fasciculus runs just medially and above the optic pathways.
Thus, the roof of ventricle is a good anatomical landmark to distinguish the ILF (below) and the inferior occipitofrontal fasciculus (above).

The initial studies of ILF described direct fibres from the occipital lobe to the temporal pole. This classical view has been challenged by several authors, who denied the existence of this direct pathway and argue for an occipito-temporal projection system from one gyrus to another (Tusa and Ungerleider, 1985; Kier et al., 2004). Using the method of DTI, allowing in vivo dissection of white matter fibres (Catani et al., 2002), recent studies have confirmed the classical anatomical description (direct pathway) and also defined U-shaped fibres of the occipitotemporal projection system (indirect pathway) (Catani et al., 2003).

Despite this anatomical progress, the understanding of the functional role of the ILF is still scarce. Indeed, most lesions (like ischaemic stroke) concern larger areas than the sole ILF, resulting in difficulties to interpret the observed neurological deficit. To our knowledge, only a case report (Ross, 1980) has suggested that the ILF could be involved in immediate visual memory.

This is the reason why, since we use intraoperative subcortical stimulation in awake patients in clinical practice, we have decided to directly map this pathway, by inducing a transient inhibition, as previously reported for other language bundles like the frontoparietal loop (Duffau et al., 2003), arcuate fasciculus (Duffau et al., 2002) or inferior occipitofrontal fasciculus (Duffau et al., 2005). Interestingly, the present study clearly demonstrates that no naming disturbance was induced, either by the stimulation or by the resection of (at least a part of) the ILF. Indeed, language disturbances observed during stimulation of white matter were induced by stimulating the bundles above the roof of temporal horn. These were semantic errors, interpreted as an involvement of the inferior occipitofrontal fasciculus, in complete accordance with our previous report (Duffau et al., 2005). In addition, stimulation performed more posteriorly and superiorly induced phonological errors (conduction aphasia), interpreted as a transient dysfunction of the arcuate fasciculus (Duffau et al., 2002). Conversely, no responses were noted for stimulation performed just laterally and under the optic pathways, the expected location of the temporoorcipital connections. Of course, such a negative result does not mean that the ILF never participates in language networks in healthy individuals: due to plasticity phenomena induced by slow growing lesion, the function could have been redistributed over the ipsi- or contralateral hemisphere (Desmurget et al., 2006). However, as for cortical areas, namely TP and Fusa, it seems that, even if the occipitotemporal projection system was involved in language networks, it could be functionally compensated after its damage—as confirmed by the complete recovery of the patient following resection.

Conclusions
As a consequence, on the basis of these results, added to our previous observations made using subcortical stimulation as well as to the neurofunctional imaging data, we suggest that the ‘ventral semantic’ stream could be constituted by at least two pathways: (i) a direct pathway, the inferior occipitofrontal fasciculus, that connects the posterior temporal areas and the orbitofrontal region, essential for language semantic processings, since it elicits semantic semantic paraphasia when stimulated (Duffau et al., 2005); (ii) an indirect pathway, the ILF [that links the posterior occipitotemporal and the TP (running below the occipitofrontal fasciculus)], then relayed by the uncinate fasciculus (not studied here), that connects the TP to the basifrontal areas: this indirect root, while joining areas involved in semantic and syntactic processing such as Fusa and TP (Vigneau et al., 2006), is not indispensable, since it can be compensated both during stimulation and after resection. It can be hypothesized that the network represented by Fusa-TP (cortical sites) and ILF (subcortical pathway) is likely compensated by the network underlied by the inferior occipitofrontal fasciculus, explaining why this bundle was essential in all patients. Therefore, we suggest that the left dominant temporal lobe is crossed by parallel distributed circuits involved in language, constituting the ‘semantic ventral stream’.

However, it is possible that the ILF-uncinate fasciculus is also involved in other functions, especially emotional processing, not tested in the present work (Catani et al., 2003). Such study is currently in progress in our institution, using a new tool of anatomofunctional correlations (du Boisgueheneuc et al., 2006).

References


