Broca's Aphasics

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Much neglected until very lately ... the convolutions were considered as a bundle without system, and the artists drew them as they might draw any dishful of macaroni. *Attributed to a late 19th century untraced German physician*

Key Words

Aphasia, Broca's • Aphemia • Leborgne ('Tan') • Lelong • Cerebral localization, language centre

Abstract

After Gall, Bouillaud and Auburtin had localized the function of language to the frontal lobes in the early 19th century, Paul Broca's famous patient, M. Leborgne (known as 'Tan'), was described to the Anthropological Society of Paris and his case was published in the *Bulletin de la Société Anatomique*, in 1861. Broca relied on the uncut brain for his clinico-pathological inferences. A few months later, his second case, M. Lelong, yielded similar pathological details and confirmed Broca's localization of language. The subsequent controversies with Dax and Pierre Marie are summarized. More recent imaging of the brains of Lelong and Leborgne has partly vindicated Broca's controversial conclusions. Most papers on Broca's work contain only brief, derivative references to his 1861 paper; the actual contents, translated into English, are reproduced here.

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The story that follows is concerned with concepts of cerebral localization, particularly of language. The history of the two famous brains examined by Broca is riddled with controversy and incident: from their mysterious disappearance and subsequent rediscovery to the very recent and brilliant reconstruction of their lesions by modern scanning techniques.

Franz Joseph Gall (1758–1828) had indicated a frontal localization for speech when he said:

'The competence to skillfully learn words and names by heart and to save them in memory is seated in the posterior part of the eye socket.'

In 1825, at the Hôpital de la Charité in Paris, Jean-Baptiste Bouillaud (1796–1881) localized language to the frontal lobes [1]. He famously offered 500 francs to whoever might demonstrate that speech disorders were not related to the frontal lobe [2]. Bouillaud proposed 2 varieties of language:

'It is quite necessary to distinguish in the act of speaking 2 different phenomena, namely, the faculty of creating words as signs of our ideas, to preserve their memory, and to articulate these

same words. There is, so to speak, an internal speech and an external speech: the latter being only the expression of the former ... The loss of speech depends sometimes on that of the memory of the words, and at other times on that of the muscular movements which constitute the words, or which is perhaps the same thing, sometimes on the lesion of the grey matter, and at other times on that of the white matter of the anterior lobes.'

On 4 April 1864, whilst addressing the Anthropological Society of Paris, Bouillaud's son-in-law, Ernest Auburtin, described an articulatory organ and a coordinating centre that resided in the frontal lobe. Auburtin [3] also localized in the frontal lobes 'the faculty of co-ordinating the movements peculiar to language', based entirely on clinical observations. However, precise localization remained in dispute.

Broca's First Paper

On 4 April 1861, at a meeting of the Anthropological Society of Paris, Paul Broca [4, 5] heard Auburtin present a paper relating his several impressive clinical studies, which he claimed supported the notion of frontal localization of language. This stimulated Broca to give his now famous communication, which he first published in the *Bulletin de la Société Anthropologique* in 1861, in which he related partial destruction of the left frontal lobe to aphasia (aphemia) [6]. The patient Broca made famous, a man called Leborgne, was nicknamed 'Tan'. Leborgne died on 17 April 1861. The next day, Broca presented the autopsy findings before the Anthropological Society of Paris and suggested that a softening of Tan's brain in the third left frontal convolution was responsible for his speech disturbance. Broca [7] kept the uncut brain specimen intact and presented his detailed findings to the Anatomical Society of Paris in August 1861.

Leborgne, aged 50, had originally been admitted to the Bicêtre Hospital at the age of 21. He had aphasia which persisted, and after 10 years he gradually developed a right hemiparesis. He was readmitted for a gangrenous leg, in April 1861. In April 1860, he had suddenly become unconscious and, although he partially recovered, he remained aphasic, able to say only 'Tan' (comparable to Baudelaire's single aphasic utterance 'Cré nom' [8]). On 4 April 1861, Leborgne suffered a diffuse, gangrenous phlegmon of the entire right inferior limb and died 6 days later. At autopsy, Broca found a lesion in the second and third left frontal convolutions that confirmed his ideas about cerebral localization of speech.

Broca's 1861 Paper

Isolated derivative quotations and references to Broca's 1861 papers abound in the literature. It may be of interest to appraise the actual contents, translated into English in the Appendix to this paper [9]. I have omitted several small sections that do not add details of the Leborgne case, and I have not reproduced Broca's lengthy, but interesting, background introduction.

Second Presentation: M. Lelong

In November 1861, Broca made his second presentation, in which he coined the term aphemia (a = without, phème = voice), and presented his second patient, M. Lelong [9]. Bouillaud then agreed with Broca's conclusions, which had confirmed his own idea of the frontal localization of language. The case of Lelong is less well known than that of Leborgne. In Broca's paper [9], Lelong is described as an 84-year-old man who, in April 1860, had suddenly become unconscious and, although he partly recovered, remained aphasic. In October 1861, the patient suffered a fracture of the femur in a fall and was transferred to the surgical service, where he died 12 days later. Broca found that Lelong was capable of uttering only 5 words: 'oui', 'non', 'toi', 'toujours' and 'Lelo' (meaning, respectively: 'yes'; 'no'; a mispronunciation of 'trois', meaning 'three', which he used for any number; 'always', and a mispronunciation of his own name).

At autopsy, Lelong was found to have a lesion in the same region of the lateral frontal lobe as that seen in Leborgne. Broca reported his findings from Lelong to the Anatomical Society of Paris, confirming the localization of speech to the frontal lobe [9]. He wrote:

'The integrity of the third frontal convolution (and perhaps of the second) seems indispensable to the exercise of the faculty of articulate language ... I found that in my second patient, the lesion occupied exactly the same seat as with the first – immediately behind the middle third, opposite the insula and precisely on the same side' (my translation).

Broca's discovery of a lesion in the left frontal second and third convolutions confirmed his ideas. He wrote:

'I will not deny my surprise bordering on stupefaction when I found that in my second patient the lesion was rigorously occupying the same site as the first.'

Fig. 1. Lateral view of Lelong's brain. **a** The frontal, temporal and parietal lobes have retracted due to severe atrophy, exposing the insula. **b** Close-up of the visible lesion in Lelong's brain. Note that only the most posterior part of what is currently called Broca's area is infarcted; the anterior portion is completely spared. Reproduced with the kind permission of the editor of *Brain* and Dronkers et al. [10].

Fig. 2. Views of the damage to Broca's area in Lelong's brain. Slices through the affected area in sagittal slice (S), in coronal slice (C) and axial slice (A). A 3-dimensional reconstruction of the left hemisphere is also shown at 512 resolution (bottom right). The widened sulci are easily visible and indicate severe atrophy. The lesion in Broca's area occupies only the posterior portion of the pars opercularis and is boxed in white. The anterior parts of Broca's area (pars triangularis and the anterior half of the pars opercularis) are still intact. Crosshairs on the 3-dimensional reconstruction indicate the orientation of the coronal and axial slices. Reproduced with the kind permission of the editor of *Brain* and Dronkers et al. [10].

As in all the patients he examined, the right side of Lelong's brain was normal. At the meeting of the Anatomical Society, Broca stated:

'The lesion occupied exactly the same seat as with the first – immediately behind the middle third, opposite the insula and precisely on the same side' [9].

In 2007, Dronkers et al. [10] using magnetic resonance imaging (see below) found with remarkable technical skill 140 years later, that 'only the most posterior part of Broca's area was actually affected in the case of Lelong' (fig. 1, 2).

Broca later distinguished two speech disorders: aphemia (expressive aphasia) and verbal amnesia (in which the patient lost the memory of both spoken and written words). He concluded:

'The integrity of the third frontal convolution (and perhaps of the second) seems indispensable to the exercise of the faculty of articulate language.'

By 1865, he had studied more patients and he deduced that 19 out of 20 aphasic patients had a left-sided lesion. He wrote: 'We speak with the left hemisphere' [11].

The well-known Broca-Dax controversy [12] ensued when Gustave Dax accused Broca of overlooking a paper written by his father, Marc Dax, in July 1836. The paper concerned 2 patients suffering from loss of memory for words, who had sustained left hemisphere injuries. The manuscript had not previously been revealed to public scrutiny but Gustave Dax nonetheless published it [13]. Critchley [14] related these intrigues in a beautifully crafted essay. He recalled mention of an 1879 article by Caizergue, who claimed to have found a copy of the original paper from Marc Dax. However, the date of the paper was not established.

Pierre Marie and Broca's Aphasia

It was 40 years later that Pierre Marie re-examined (but did not section) Tan's brain and claimed that the lesion was larger than Broca had asserted, extending from the third frontal convolution into the white matter and into the external capsule. Marie wrote scathingly, and criticized Broca's findings with the title to his paper: 'La troisième circonvolution frontale gauche ne joue aucun rôle spécial dans la fonction du langage' (The left third frontal convolution plays no special role in the function of language) [15]. Marie did, however, acknowledge that Broca's second patient (Lelong) suffered from aphemia and that his lesion was confined to the third frontal convolution [16].

Pierre Marie's ideas [17] were based on Moutier's thesis, which was based on other brains, and he fought at length with Joseph Jules Déjerine [18] who had broadly supported Broca's conclusions. Marie largely failed in this battle against Déjerine when he had his concepts destroyed by Augusta Déjerine-Klumpke in the 1905 aphasia quarrel. Marie dismissed Moutier and effectively wiped out his neurological future.

Imaging of the Brains Studied by Broca

Although originally in the Musée Dupuytren, the brains were removed in 1940 after the museum walls had collapsed. The brains were originally believed to be lost, but Schiller [5] describes finding in 1962 the brains of Leborgne and Lelong in the basement of the École de Médecine in Paris, where they had rested since 1940. In 1979 Signoret retrieved and removed the Leborgne brain, and photographed and scanned it by computerized tomography [19, 20]. The scans confirmed that the damage was

restricted to Broca's area and the insula, but spared Wernicke's area. Lelong's brain remained uncut and unscanned in the same show window at the École de Médecine.

Dronkers et al. [10], in a recent investigation, used high-resolution magnetic resonance imaging of the preserved brains of both of Broca's historic patients. Figures 1 and 2 show the widened sulci that indicate severe atrophy. The lesion in Broca's area occupies only the posterior portion of the pars opercularis. The anterior parts of Broca's area (pars triangularis and the anterior half of the pars opercularis) are intact. Three-dimensional reconstruction showed that in Lelong and Leborgne the lesions extended significantly into the medial regions of the brain, in addition to the surface lesions observed by Broca. The results indicate inconsistencies between the area originally identified by Broca and what is now called Broca's area [10]. However, it is important to note that after Broca, the so-called Broca's area was redefined and currently differs from Broca's original description. Dronkers et al. observed that:

'Quite different from what we have been seeing in the literature later in his writings Broca thought that it was really a very large part of the inferior frontal gyrus that might have something to do with speech and language function ... So, there was really quite a range across the inferior frontal gyrus that Broca observed.'

Recent neurolinguistic studies suggest Broca's patient suffered global, not expressive, aphasia. Dronkers [21] stresses that the findings do not in any way detract from Broca's outstanding work. Broca had, in fact, noted that Leborgne's lesions extended posterior to the third convolution of the frontal lobe, but suggested that this damage had occurred after the onset of Leborgne's aphasia and that it was unrelated to the speech disturbances. During his examinations, Broca had actually chosen not to dissect the brains, so could only assess the superficial damage, and only inferred the extent of the damage to deeper structures. Dronkers wrote [21]:

'Fortunately, Broca had the foresight in preserving these historic brains and, in some ways, Leborgne and Lelong can speak to us more eloquently now than they could over 140 years ago.'

Conclusion

Neither the idea of a faculty of articulate language nor the concept of its localization at the front of the brain was new in Broca's time [22]. But Broca's detailed account

Fig. 3. Broca in 1867. From the Académie nationale de médecine.

[23], his search for the cause of the patient's aphemia, his use of the pathological method (rather than Gall's craniological one) and his attention to individual cerebral convolutions explain the immediate and extraordinary reactions to his work, and justify the eponym Broca's aphasia.

Whether Bouillaud, Broca or Marc Dax deserves priority is now of little moment. Broca's concluding comments encapsulated the situation and remain relevant:

'If all cerebral faculties were as distinct and as clearly circumscribed as this one, we would finally have a definite point from which to attack the controversial question of cerebral localization ... In this respect science has so little advanced that it has not even found its base, and what is today in doubt is ... the principle of localization itself.'

Broca's controversial work confirmed the earlier opinions of Bouillaud and Auburtin. The fate of the brains of Leborgne and Lelong and their eventual resurrection is a remarkable adventure in the history of medicine. Broca (fig. 3) was an unusual man, distinguished as surgeon, pathologist and anthropologist, and regarded as generous, compassionate and kind, with unbreakable fortitude and honesty. He was, at times, embroiled in personal controversy. He founded a society of freethinkers and he supported Darwin's views on evolution. But he did achieve recognition. He was appointed in 1867 to the chair of pathologie externe at the Faculty of Medicine, Paris; in 1868

he became professor of clinical surgery; 6 months before his death he was elected a member of the French Senate for life and vice-president of the French Academy of Medicine. Broca was responsible for the formation of the Anthropological Society of Paris (in 1859), and received honorary degrees from several academic institutions. He died suddenly (possibly of aneurysmal subarachnoid haemorrhage) at the age of 56 in Paris on 8 July 1880.

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Appendix

Remarques sur le siège de la faculté du langage articulé, suivies d'une observation d'aphémie (perte de la parole)

M. Paul Broca, Chirurgien de l'Hôpital de Bicêtre. First published in the *Bulletin de la Société Anatomique* 1861;6:330–357, translation by Christopher D. Green.

On 11 April 1861, transported to the general infirmary of Bicêtre, surgery service, was a 50-year-old man, named Leborgne, suffering from a diffuse, gangrenous phlegmon of the entire right inferior limb ... To the questions that I addressed to him the next day on the origin of his malady, he responded only with the monosyllable 'tan', repeated two times in sequence, and accompanied by a gesture of his left hand. I went for information on this man's history, who had been at Bicêtre for 21 years ... He was subject, since his youth, to attacks of epilepsy; but he had been able to take up the trade of a hat-form maker [prendre l'état de formier] that he exercised up to the age of 30. At this time, he lost the ability to speak, and it was for this reason that he was admitted as a patient to the hospice of Bicêtre. We did not know if the loss of speech came on slowly or rapidly ... When he arrived at Bicêtre ... he was then perfectly healthy and intelligent, and differed from a sane man only in the loss of articulated speech ... He understood all that was said to him; he even had very fine hearing; but, regardless of the question addressed to him, he always responded: 'tan, tan' ... He was considered, on the contrary, as a man perfectly responsible for his acts.

He had already been without speech for 10 years when a new symptom appeared: the muscles of his right arm gradually weakened, and finally became entirely paralyzed. Tan continued to walk without difficulty, but the paralysis of movement won little by little the right inferior limb, and, after having dragged his leg for some time, the patient had to resign himself to keeping constantly to bed ... It was, therefore, close to 7 years that Tan was in bed before he was brought to the infirmary ... It was noticed that his vision had declined notably over about the previous 2 years. This was the only complication noticed ... the widespread phleg-

mon, for which he was transported to the infirmary on 11 April 1861, was recognized by the nurses only when it had progressed considerably and had invaded the totality of his right [lower] limb, from the foot to the buttock.

The study of this unfortunate person, who could not speak and who, being paralyzed in the right hand, could not write, presented quite a few difficulties. He was moreover in such a generally grave state that it would have been cruel to torment him with lengthy investigations.

I noted however that his general sensitivity was everywhere preserved ... The 2 right limbs were completely paralyzed of movement ... The emission of urine and faecal matter was natural, but swallowing was done with some difficulty ... the muscles on this side of the face were a little weakened. There was no indication of strabismus. The tongue was perfectly free ... the quality of the voice was natural, and the sounds that the patient made in pronouncing his monosyllable were perfectly clear.

It is certain that Tan understood almost everything that was said to him; but, he could only express his ideas or his desires by the movement of his left hand ... I asked him many times how many days he had been sick? He responded sometimes 5 days, sometimes 6 days. For how many years had he been at Bicêtre? He opened his hand 4 times in sequence, and then pointed with a single finger; this would make 21 years, and one saw above that this information was perfectly exact ... It is therefore incontestable that this man was intelligent, that he could reflect, and that he had preserved, in a certain measure, his memory for things past. He could even comprehend relatively complicated ideas ...

It was seen clearly ... that there existed a progressive cerebral lesion that, originally and during the first 10 years of the sickness, was kept limited to a relatively circumscribed region ... the principal cerebral lesion had to occupy the left hemisphere, and what confirmed this opinion was the incomplete paralysis of the muscles of the left cheek and the retina of the same side ...

It was a matter of determining more exactly, if possible, the seat of the original lesion ... Mr. Auburtin, having declared some days before that he would renounce it if one could show him a single case of aphemia, well-described, without a lesion to the anterior lobes, I invited him to come see my patient ... [he affirmed] that the lesion must have started in one of the anterior lobes ...

The probable diagnosis was therefore: original lesion in the left anterior lobe, propagated to the striate body of the same side. As for the nature of this lesion, everything indicated that it was a matter of a progressive, chronic softening, but extremely slow, for the absence of all phenomena of compression excluded the idea of an intracranial tumour.

The patient died on 17 April, at 11 o'clock in the morning. The autopsy was done as soon as possible, that is to say, at the end of 24 h ... The brain was shown a few hours later to the Anthropological Society, then placed immediately in alcohol ... Today it is in perfect condition, and it is deposited in the Dupuytren museum under No. 55a of the nervous system ...

All the viscera were healthy, except the brain. The skull was opened with a saw with a great deal of care ... The dura mater and the false membrane together had an average thickness of 5 mm (minimum, 3 mm; maximum, 8 mm), from which it necessarily follows that the brain must have lost a notable portion of its original volume.

Lifting the dura mater, the pia mater appeared very perforated [injectée] at certain points. It was thick throughout, and, in places, was opaque and infiltrated with a plastic yellowish material that had the colour of pus, but that was solid, and that, when examined through a microscope, did not contain purulent globules.

On the lateral part of the left hemisphere, at the level of the sylvian fissure, the pia mater was raised by an amount of transparent serous fluid, that was lodged in a large and deep depression of the cerebral substance. This liquid was evacuated ... resulting in the opening of a long cavity of capacity equivalent to the volume of a chicken egg, connected to the sylvian fissure, and separating thereby the frontal lobe from the temporal lobe. It extended at the rear up to the level of the sulcus of Rolando ... The lesion was, therefore, situated throughout the entire region in front of this sulcus, and the parietal lobe was healthy, at least relatively speaking [d'une manière relative], for no part of the hemispheres was in a state of absolute integrity.

In cutting and peeling back [écartant] the pia mater at the level of the cavity I have here described, one recognized at first glance that this corresponded not to a depression, but to a loss of substance of the cerebral mass ... A notable part of the left hemisphere had thus been destroyed gradually; but the softening extended well beyond the limits of the cavity; this was by no means circumscribed, and cannot under any circumstances be described as a cyst ...

In summary, as a consequence, the destroyed organs are the following: the small inferior marginal convolution (temporoparietal lobe); the small convolutions of the lobe of the insula, and the part subjacent to the striate body; finally, on the frontal lobe, the inferior part of the transversal convolution, and the posterior half of the 2 great convolutions designated by the name of second and third frontal convolutions. Of the 4 convolutions that form the superior layer of the frontal lobe, 1 alone, the first and the most internal, did not preserve its integrity, for it is softened and atrophied, but did preserve its continuity; and if one imaginatively restores [rétablit par la pensée] all the parts that have been destroyed, one finds that at least three quarters of the cavity that has been hollowed out come from the frontal lobe.

Now remains to be determined the location at which the lesion must have begun. Now, examination of the cavity left by the loss of substance shows first of all that the centre of its focus [foyer] corresponds to the frontal lobe ... It is, therefore, primarily in this lobe that the softening was propagated, and it is almost certain that the other parts were invaded subsequently.

If one were looking to be more precise, one might remark that the third frontal convolution is that which presents the most extensive loss of substance, that it is not only cut across the level of the anterior extremity of the sylvian fissure, but still is entirely destroyed throughout its posterior half, that it alone has suffered a loss of substance equal to about half of the total loss of substance; that the second convolution, or middle convolution, although very profoundly damaged, still preserves the continuity of its most internal part, and that as a consequence, according to all probabilities, it is in the third frontal convolution that the disease began.

The other parts of the hemispheres are relatively healthy ...

As for the deep parts, I abstained [renoncé] from studying them, so as not to destroy the specimen, which it seemed important to me to deposit in the museum. However, the opening that

connects the exterior to the anterior part of the left lateral ventricle was, despite my efforts, enlarged during the dissection of the pia mater so that I was able to examine half the internal surface of this ventricle, and I saw that all of the striate body was more or less softened, but that the optic stratum maintained [avait] its colour, its volume and its normal consistency.

The whole encephalon, weighed with the pia mater, after evacuation of the liquid that filled the focus, was not greater than 987 g. It is, therefore, almost 400 g lighter than the average weight of the brains of 50-year-old men ...

After having described these lesions, and researched their nature, seat and anatomical progression, it is important to compare these results with those of clinical observation, to finally establish, if possible, a connection between the symptoms and the material disorders ...

This drives us to admit that from the point of view of pathological anatomy, there had been 2 periods: one in which only 1 frontal convolution (probably the third) was altered; the other, in which the illness propagated itself little by little to the other convolutions, to the lobe of the insula or to the extraventricular nucleus of the striate body.

If now we examine the succession of symptoms, we find equally 2 periods: a first period which lasted 10 years, during which the faculty of language was abolished, and when all the other functions of the encephalon were intact; and a second period of 11

years, during which a paralysis of movement, at first partial, then absolutely complete, successively invaded the superior limb and the inferior limb of the right side.

Having said this, it is impossible [not] to recognize that there had been a correspondence between the 2 anatomical periods and the 2 symptomological periods. Or to ignore that the cerebral convolutions are not motor organs. The striate body of the left hemisphere is, therefore, of all the organs damaged [lésé], the only one in which one can find the cause of the paralysis of the 2 right limbs. The second clinical period, that in which motility was altered, corresponds also to the second anatomical period, that is to say, to that in which the softening, overflowing the limits of the frontal lobe, reached the insula and the striate body.

Thus, the first period of 10 years, characterized clinically by the unique symptom of aphemia, must correspond to the phase [époque] in which the lesion was still limited to the frontal lobe ...

One can scarcely understand that the patient was able to retain any intelligence at all, and it does not seem probable that one could live very long with this kind of brain ... I am disposed to believe that these lesions came about a long time after the softening of the striate body, of the sort that one could subdivide the second period into 2 secondary periods, and in doing so, summarize the history of the patient.

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