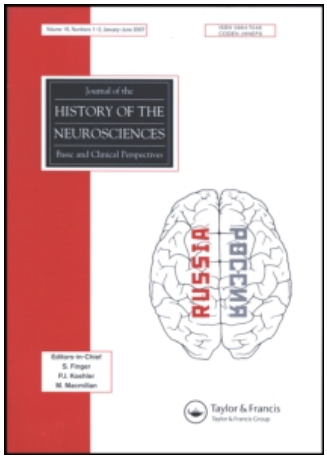

Journal of the History of the Neurosciences
Basic and Clinical Perspectives
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713658018

Production and Reception of Meaningful Sound in Foville's 'Encompassing Convolution'

Francis Schiller

Online Publication Date: 01 April 1999
To cite this Article: Schiller, Francis (1999) 'Production and Reception of Meaningful Sound in Foville's 'Encompassing Convolution'', Journal of the History of the Neurosciences, 8:1, 51 - 59
To link to this article: DOI: 10.1076/jhin.8.1.51.1769
URL: http://dx.doi.org/10.1076/jhin.8.1.51.1769

Journal of the History of the Neurosciences
1999, Vol. 8, No. 1, pp. 51–59

0964-704X/99/0801-051$15.00

Production and Reception of Meaningful Sound in Foville's 'Encompassing Convolution'*

Francis Schiller
University of California Medical School, San Francisco

ABSTRACT

In the history of neurology, Achille Louis Foville (1799–1879) is a name deserving to be remembered. In the course of time, his *circonvolution d'enceinte* of 1844 (surrounding the Sylvian fissure) became the 'convolution encompassing' every aspect of aphasiology, including amusia, i.e., the localization in a coherent semicircle of cerebral cortex serving the production and perception of language, song and instrumental music in health and disease.

Keywords: Language, music, and the brain.

INTRODUCTION

While assigning mental functions to the ventricles of the brain goes back to antiquity, the solid parts of the brain received only little attention before the Renaissance. Subdividing them did not become an anatomical concern before Constanzo Varolio (1543–1575) in 1573 designated three prominentiae surrounding each of the three ventricles as an anterior, middle and posterior ''lobe''. (He is better known for *pons Varolii*, mainly concerned with the cerebellum, which he described in a later work (Varolio, 1591). A century later, Thomas Willis (1621–1675), in his famous *Cerebri anatome* of 1664, divided the brain into two lobes: anterior and posterior (Willis, 1983). It is with François B. Chaussier (1746–1828) in Paris, 1807, that we get a description of four lobes in his *Exposition Sommaire de la Structure et des Différentes Parties de l'Encéphale ou Cerveau* (''Summary Exposition of the Structure and the Different Parts of the Encephalon or Brain'': Chaussier, 1807). A fifth, central, lobe, (Reil's *insula*, 1796) is described in 1854 in Louis Pierre Gratiolet's *Mémoire sur les Plis Cérébraux de l'Homme et des Primates* (''Treatise on the Cerebral Folds of Man and Primates'': Gratiolet, 1854).

Unconcerned with any kind of classification of function, the earliest observers of the brain drew only little attention to its odd-looking surface. In the Breasted edition of the Edwin Smith Surgical Papyrus (the original document dates back to around 2600 BC) what became the cerebral convolutions was simply a messy kind of substance looking like ''metal slag'': the refuse from smelting copper (Breasted, 1930). Around 300 BC, in Alexandria, Erasistratus, according to Galen, wrote that, 'since man greatly surpasses other beings in intelligence, his brain is greatly convoluted' (Clarke, 1996, p. 12). Erasistratus is again quoted by Vesalius (1514–1564) in his *Fabrica* of 1543 'The gyri [Greek for rings or circles] or convolutions of the brain which Erasistratus very nicely compared to the small intestines...I believe that they cannot be more happily compared to clouds...' (Clarke, 1996, p. 386). Here we see 'Enteroid processes' then: associated with the shape of the gyri, the low opinion of their function persisted. The Danish professor Thomas Bartholinus in his *Anatomia Reformata* of 1656 still confirms that

* Address correspondence to: Francis Schiller MD, 2730 Wawona, San Francisco, CA 94116, USA.

'convolutions have the appearance of intestines; they are not made for the intellect as Erasistratus holds – asses have them too' (Clarke, p. 390). In this context and at about the same time, François Dubois (de la Boë or Sylvius [1614–1672]), pointed out his 'notable *fissure* or *hiatus*'. It was based on his observation in 1663 that 'the whole surface of the cerebrum is everywhere deeply marked by gyri, similar to the convolution of small intestine and especially' by that main fissure (Clarke, 1996, p. 391). By then Thomas Willis had elevated the functional status of the 'cerebral folds and convolutions' to 'closets and storehouses' (*cellulis et apothecis*) 'for the storage of sensory impressions' (Willis, 1983, p. 91).

Few new ideas and little progress in this field was made in the 18th century except toward the end in the Vicq-d'Azyr atlas of the brain (1786). Here the artist (Angélique Briceau) anticipated the vertical fissure and adjacent convolution that were to carry the name of Luigi Rolando (1773–1831): his 'middle vertical processes *processi verticali di mezzo*'. Rolando saw them arising at right angles from what he also considered to be a single convolution, one that entirely surrounds the horizontal Sylvian fissure. But Rolando did not name them (Rolando, 1809).

Thirty-five years later a Frenchman, anatomist of the brain as well as psychiatrist, divided the convolutions into three major entities, calling them the 'great regions of the brain': superior, medial, and inferior; or first, second, and third order. He did so merely on anatomical grounds: the time for the cortical localizations of function was only in its blundering infancy. To his second convolution he gave the name *circonvolution d'enceinte* as it surrounds the Sylvian fissure (Foville, 1844. See Fig. 1) This later turned out to be associated with our aggregate of cortical locations, representing most if not all of functions involved in language and music.

FOVILLE

Achille Louis François Foville (1799–1878) was born in Pontoise (Seine-et-Oise district) and assisted two of the important founders of French psychiatry. The first was Léon Louis Rostan (1790–1866) at the Asylum of Rouen, whom he succeeded as chief in 1825. Even more important was his succession of Jean Etienne Dominique Esquirol (1772–1840) at Charenton. He had to decline the suggestion of Thomas Hodgkin (1798–1866) (the great clinician pathologist and philanthropist of Guy's and St. Thomas Hospital in London) to cofound a counterpart of Tuke's York Retreat in Southern England (Cherry, 1979).

Foville's doctoral thesis of 1824 was entitled ''Observations cliniques propres a éclairer certaines questions relatives a l'aliénation mentale'' (''Clinical Observations to Throw Light on Certain Questions concerning Mental Alienation''), stressing their curability (Ritti, 1878). The *Dictionnaire Encyclopédique des Sciences Médicales* of 1879 credits Foville with being 'The first to establish the fact that the cortical substance of the brain is made to perform the functions of the intellect'. But in the course of time, Foville's idea of an encompassing gyrus was disregarded as the convolutions began to be named according to the surrounding lobes: frontal, parietal, temporal, and occipital. Yet Foville's idea seems worthy of being rescued from oblivion when we consider the series of discoveries that linked the affected cortical areas to the physiological production and reception of speaking and singing, hearing, as well as understanding and appreciating sounds. (In most textbooks of neurology Foville's name appears as the eponym of the pontine infarct paralysing conjugate vision, the pyramidal tract on one side, and the face on the other which he described in 1844.)

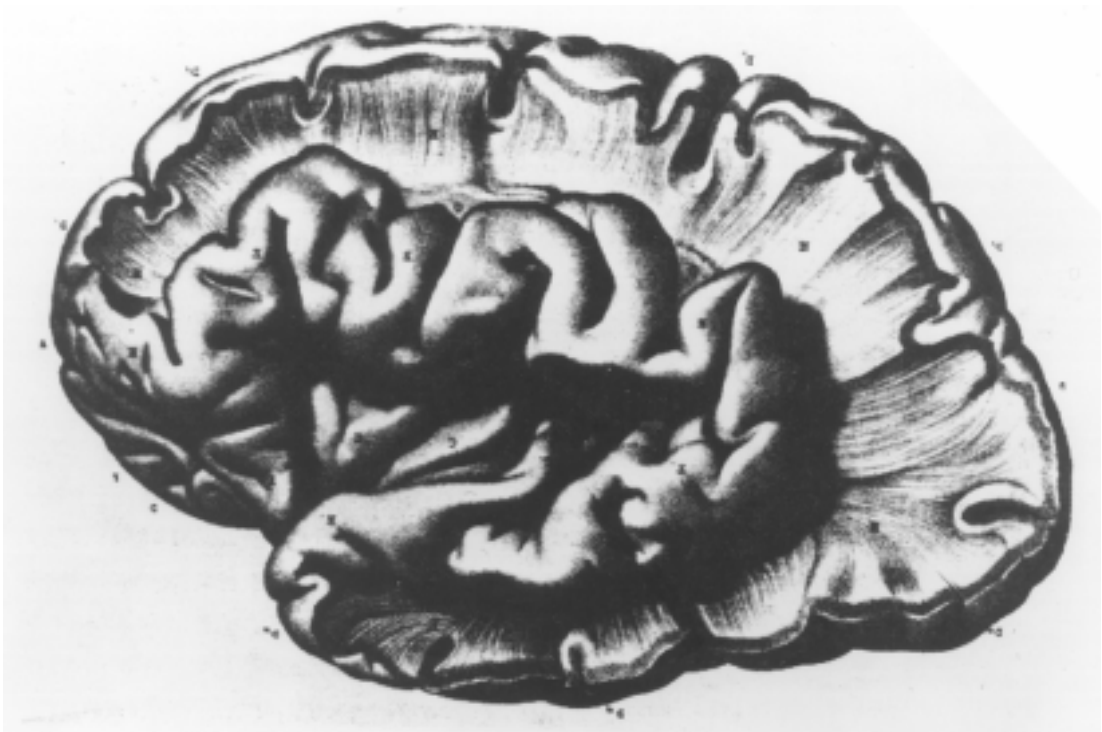

Fig. 1. Achille Louis Foville's *circonvolution d'enceinte* – ''encompassing convolution'', 1844.

SPEECH

Aphasiology focussed on distinct cortical areas practically began with Broca's patient 'Tan' (Leborgne) of 1861 and his 'softened' base of the left third frontal convolution (Broca, 1861). This was the superior anterior portion of Foville's arc, and in one of his later papers dealing with the laterality of speech localization, Broca reported the case of a lefthanded non-aphasic woman with a congenital right hemplegia. At autopsy her brain showed a complete absence of what Broca called the 'convolution of speech', i.e., the gyrus of Foville surrounding the left Sylvan fissure (Broca, 1866). Broca did not fail to draw attention briefly to Foville's work (Broca, 1863): 'Instead of being exclusively localized in the posterior portion of the third frontal convolution', he asked, 'might the seat of articulate speech not extend to the inferior parietal convolution which is directly continuous with it...All this is still too hypothetical...Several anatomists are known to consider the two convolutions as one, calling them the convolution around the Sylvian fissure… *circonvolution d'enceinte*, Foville...'

Next, most accounts of aphasiology refer to Wernicke's discovery of sensory aphasia in 1874 as the ensuing major event. While it had such a great impact, he also had two forerunners in this matter. The first was eight years earlier, in 1866, when Theodor Meynert (1835–1892), the 33-year-old Dresden-born director of the Psychiatric Clinic and Professor of Nervous Disease in Vienna, described a case with loss of understanding speech and paraphasias showing a lesion in the posterior part of the left superior temporal gyrus and adjacent planum temporale. (Meynert happened to have not only Wernicke, but later also Freud, as his students [Seitelberger, 1997].)

Three years after Meynert, but still five years before Wernicke, Bastian's contribution appeared. Henry Charlton Bastian (1837–1915)

came from Truro in Cornwall, became professor of pathological anatomy at University College, London, and Fellow of the Royal Society in 1868. The somewhat obscure *British and Foreign Medico-Chirurgical Revue*, London, 1869, printed his paper entitled ''On the Various Forms of Loss of Speech in Cerebral Disease.'' Here he described a patient who had 'lost his memory for words... We think in words, in fact, and these words are received as sound impressions in the auditory receptive centres of the cerebral hemisphere' (Bastian, 1869). There was no autopsy, but many similar cases described later pointed to the left superior temporal convolution. Bastian's 1880 work, *The Brain as an Organ of Mind*, was translated into French and German and, in 1898, his *Treatise on Aphasia and other Speech Defects* was published.

Five years after Bastian's initial contribution, in 1874, Carl Wernicke (1848–1905), born in Upper Silesia, practicing in Berlin, Breslau and Halle, left his impact on the posterior superior temporal part of Foville's convolution. Wernicke was 26 when he published *Der Aphasische Symptomenkomplex* in 1874. He divided his 'symptom complex' into four groups: (1) motor aphasia, (2) sensory aphasia, (3) conduction aphasia (fluent, predominantly lexical, excellent repetition in contrast with poor comprehension and semantic confusion), and (4) 'total aphasia'. His diagram shows the connections covering Foville's convolution, but without referring to it. Severe aphasia did not necessarily include deafness. Wernicke also wrote a three-volume psychiatric textbook *Diseases of the Brain for Physicians and Students*. Aged 50, he died in an accident riding his bicycle (Goldstein, 1970).

HEARING

Our next important contributor is the Scotsman David Ferrier (1843–1928), who worked in London at the National Hospital and Kings College. He was a neuropathologist, physiologist, and cofounder of the journal *Brain*. In his book *The Functions of the Brain*, 1876, Ferrier assures his readers that 'Broca and his observations have

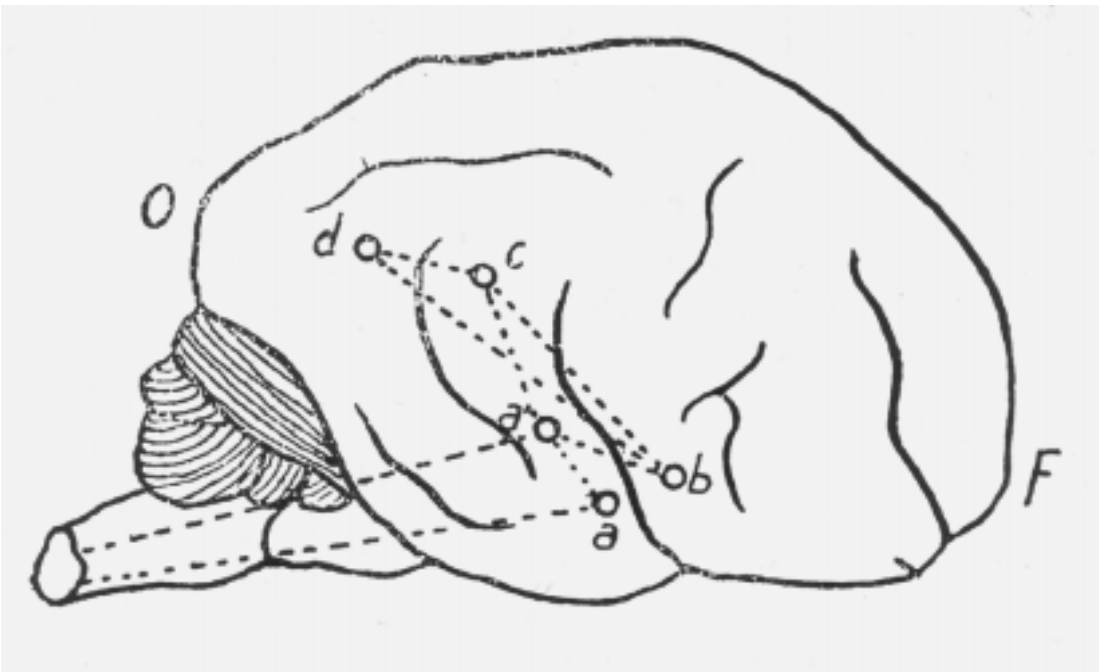

Fig. 2. Wernickes' diagram (1874). O occipital, F frontal, A auditive center, B vocal emission center of motor representation, C associated tactile images, D center of optic images.

been confirmed by thousands of other cases...', going on to say that 'the posterior extremity of the third left-frontal convolution, where it abuts the fissure of Sylvius...[is] a region which I have shown corresponds with the situation of the motor centres of articulation in the monkey...' He also refers to 'Opponents of localization...cases of aphasia without lesions in this area, and cases without aphasia with such lesions.' Testing for the localization of hearing in the monkey, he electrically irritated the superior temporo-sphenoidal gyrus with the result that the animal pricked the opposite ear, as if it were reacting to a noise on that side. But it requires bilateral destruction of the superior temporo-sphenoidal convolution, Ferrier found, to produce complete and permanent loss of hearing. Hearing is not impaired by a lesion of any other part of the temporal lobe (Ferrier, 1876).

Denial of Ferrier's cortical localization of sound perception was not far behind. Edward Albert Schaefer (later more English as Sharpey-Schäfer, 1850–1935), also working in London in collaboration with Sanger-Brown from Chicago, and with the pioneer neurosurgeon Victor Horsley, had found 'No evidence of impairment of abolition of hearing, smell or taste in removing both temporal lobes...no deafness' Schaefer's subjects were also monkeys (Schäfer, 1888a). He did acknowledge Ferrier's reputation: 'Few men have done so much towards the elucidation of the cerebral function as my present opponent', but added 'that we have finally settled the question involved, I should be the last to affirm' (Schäfer, 1888b). One reason for the prolonged controversy regarding the cortical localization of sound perception is that each ear transmits its stimuli to both hemispheres, and that hearing may recover after weeks or months depending on the extent of temporal lobe destruction.

On the basis of clinical, electroencephalographic, and pathological evidence, it was finally accepted that cortical representation of hearing was essentially in the transverse temporal convolution. This was first described by the Styrian (Austrian) Hofrat Professor Richard Ladislaus Heschl (1824–1881) in 1878, and named after him, but without any original functional attribution by him. By 1907 Sir Frederick Walker Mott (1853–1926) of the London Maudsley Hospital, a former assistant of Schaefer, reported *Bilateral Lesion of the Auditory Cortical Centre: Complete Deafness and Aphasia* (Mott, 1907). In 1942 Clinton N. Wolsey and E.M. Walzl at Johns Hopkins in Baltimore, recorded the acoustic representation in the cat brain around the suprasylvian sulcus or the middle ectosylvian cortex, i.e., around the posterior end of Foville's encompassing convolution. Only bilateral removal of the infra-sylvian gyrus may produce complete deafness. Walter Dandy (1886–1946), the pioneering neurosurgeon, after performing a right hemispherectomy concluded that there was no unilateral hearing center, right or left (Dandy, 1933).[1]

MUSIC

An important functional aspect involving Foville's convolution is the production and appreciation of music. The term 'music' is not as easy to define as is verbal language. While they share the acoustic aspect as well as motor functions, and while both can also be expressed graphically and have an emotional impact, music lacks the logical precision of speech. Yet even speech has 'intonation'; in song they are combined; birds sing and humans play instruments. But whereas speech is commonly confined to one hemisphere, no strict laterality seems applicable to music.

Not long after the cerebral localization of speech was established in the 1860's and 1870's, a few reports appeared on aphasic patients either having or not having lost their musical ability as well. In 1865, the Paris Academician Jean-Baptiste Bouillaud (1796–1881), teacher and supporter of Broca, drew attention to an aphasic musician who could still accompany singers on the piano, hum and even compose music (Bouillaud, 1865). As early as 1745, a Swedish historian and litterateur, Olaf Dalin

[1] For an extensive account of the controversy, see Stanley Finger's *Origins of Neuroscience* (1994).

(1705–1763), had described a farmer's son who, with a 'violent illness' had lost the movement of his right limbs and could not speak except for saying 'Yes,' but could recite some prayers and sing some hymns (Benton & Joynt, 1960). In 1864 a doctor at the Salpêtrière, Jules Falret (born 1824), wrote of 'patients who can hardly speak any more and nevertheless can still sing' (1864). In 1870, Karl Maria Finkelnburg (1832–1896), a psychiatrist in Berlin, in the same paper in which he coined the term 'asymbolia', described a lefthanded musician with amnesic aphasia and agraphia due to disease of the right hemisphere. While he could reproduce melodies on his violin, he was unable to do so on the piano. The famous author of *A Manual of Diseases of the Nervous System*, William Gowers (1845–1915), in 1875 described as 'almost speechless' a patient who had suffered an embolism of the left middle cerebral artery, but who joined 'a singing patient, continued to sing the words and melody of several verses by himself' (Gowers, 1875). Experiments of 'dichotic listening', i.e., using a technique able to block one or the other ear, performed by Doreen Kimura in 1967, allowed her to conclude that the left ear, hence the right hemisphere, is the more efficient one (Kimura, 1967).

The term 'amusia' was coined in 1888 by Alexander K. Knoblauch (1820–1899) in Frankfurt. He described a patient with right hemiplegia and aphasia who still, if only just, could sing a popular folksong (Knoblauch, 1888). The first detailed analysis of amusia was published by the Swedish doctor Johan G. Edgren (1849?–1920). In 1895 he showed that aphasia without amusia was as common as their coexistence, but amusia alone, without aphasia, rarely occurred (Edgren, 1895). In 1937 Otto Pötzl and Herbert Uiberall in Vienna stated that receptive amusia may result from damage of either temporal lobe, but more so from the right. By 1962 it was again claimed that the right hemisphere was overwhelmingly concerned with musical ability (Milner, 1962). In the 1970's it was confirmed that righthanded, markedly aphasic musicians due to left hemisphere lesions will preserve their capacity to conduct, compose, play the piano and generally recognize melodies (Assal, 1974). As an explanation, Joseph E. Bogen and Harold W. Gordon showed in 1971 with the Wada amobarbital test (by which either hemisphere is anesthetized separately), that a block of the dominant left hemisphere would leave singing unimpaired despite the resulting aphasia. Right hemisphere block produced expressive amusia and loss of pitch control. The patients examined here were epileptic nonmusicians (1971). In 1974 it was suggested (or even claimed) that the nondominant right hemisphere is holistic in its effect on music, while the more sophisticated left brain remains dominant for detailed musical receiving (Bever & Chiarello, 1974).

In 1906, J. Jules Déjerine (1849–1917) associated *amusie* with *aphasie*: In singing a song, its words were as defective as in the spoken jargon. Another patient with sensory aphasia, unable to read or write from dictation, had preserved her appreciation of music and could sing correctly (Amidon, 1885). And there was the Russian composer Shebalin who, after a stroke causing Wernicke's aphasia with agraphia and alexia, could still compose (Luria et al., 1965), 'a complete mystery' according to Arthur Benton (1977). When in 1933, aged 58, the famous composer Maurice Ravel (1875–1937) suffered a left hemisphere stroke, he showed moderate aphasia of a mixed type, also agraphia and apraxia, and possible alexia. Yet although all his musical abilities were also impaired, he maintained a good recognition of tunes, and could complete singing a tune when the first notes were given, as well as appreciate and judge what was being played to him (Alajouanine, 1948). As to hearing music, in a patient some of whose epileptic seizures were triggered by hearing a tune, Wilder Penfield and Theodore Rasmussen reproduced the aura of organized sound by stimulating the right first temporal convolution. To their work we owe the precise localization of the speech organs, lips, tongue and throat, sensory and motor, in the inferior quarters of the postcentral and precentral gyrus, respectively (Penfield & Rasmussen, 1955). In 1974 ''Melodic Intonation Therapy (MIT)'' was

recommended for aphasic patients (Sparks et. al., 1974) .[2]

CONFLICT AND CONCLUSION

Perhaps not surprisingly, there were always some reputable opponents of precise motor and sensory localization of speech or music. Above all, the basic dichotomy of mind and matter did not allow its adherents to ''localize'' speech in the way Broca, Wernicke, and others had indicated. Henri Louis Bergson's (1859–1944) *Matière et Mémoire* of 1896 was perhaps the most outstanding example. In it he wrote that:

> The cerebral organ prepares the frame; it does not furnish the recollection. That is what the maladies of word memory teach us... If the frame be there, the recollection will come of its own accord to insert itself in to it.... (1896, p. 91) The cerebral phenomena are to the mental life just what the gestures of the conductor are to the symphony: they mark out the motor articulations, they do nothing else. In other words we should find nothing of the highest workings of the mind within the cerebral cortex... (p. 92).

The leading neurological opponent was Pierre Marie (1853–1940). His harsh, almost devastating critique of Broca's work in 1906 culminated in the famous phrase: ''The third frontal convolution has no role whatever in the function of speech'' (Marie, 1906). For Marie there existed two main categories: (1) Mechanical *anarthrie*, and (2) *aphasie* 'due to a general intellectual defect' (Marie, 1906). Twenty years after Marie's another critical work was published in London: the two big volumes *Aphasia and Kindred Disorders of Speech* (1926) by Henry Head (1861–1940). While he classified aphasia linguistically into 'verbal', 'nominal', 'syntactical', and 'semantic', he asserted that 'there are no ''centres'' for the use of language in any form', adding somewhat ambiguously 'but solely certain places where an organic lesion of the brain can disturb speech in some specific manner' (Head, 1926).

Preceding Henry Head and even Pierre Marie, there was Sigmund Freud's (1856–1939) critical masterpiece of 1891: *Zur Auffasung der Aphasien* (''About the Conception of the Aphasias''), translated by Stengel as *On Aphasia*. Somewhat critical of all his predecessors for having over-rated localization, Freud arrived at a compromise concluding that 'The separation of speech therefore presented itself to us as a continuous cortical area in the left hemisphere extending between the termination of the acoustic and optic nerves and the origins of the motor tracts for the muscles serving articulation and arm movements'. (No mention of the Sylvian fissure or Foville) (Freud, 1891).

CONCLUSION

As the experience of the subject – gathered over many decades – has shown, there is some limitation to the precision with which we can analyze, classify, and localize speech and its associated disorders. The lack of precise psycho-linguistic parameters finds its analogy in the supposed cortical boundaries separating functional areas. Hence Foville's convolution unifying all these parameters deserves to be remembered by aphasiologists. Without mentioning his name, Weisenburg and McBride, in their 1937 work on aphasia, wrote that 'the lesion... must implicate ...the lower portion of the precentral convolution and probably the adjoining part of the frontal lobe, the upper part of the temporal lobe, and the anterior part of the occipital'. (1937) André Ombrédane, in his work on aphasia of 1951, also wrote: 'From the confrontation of such varied clinical pictures of aphasia and from subsequent anatomical findings, one can conclude that the region consisting of the convolution which surrounds the Sylvian valley... is a speech center' (1951).

[2] Already by 1867, Theodor Meynert (1833-1892), before the experiments on the motor cortex by Fritsch and Hitzig in 1870, had divided the cortex into anterior motor and a posterior sensory portion (Seitelberger, 1997).

REFERENCES

Alajouanine T (1948): Aphasia and artistic realization. *Brain 71*: 229-241.

Amidon RW (1885): On the pathological anatomy of sensory aphasia. *New York Med J, Jan*.:115-116, 181-184.

Assal G (1974): Wernicke's aphasia without amusia in a pianist. *Rev. Neurol 29*: 251-258.

Bastian HC (1869): On the various forms of loss of speech in cerebral disease. *Brit. For. Med. Chir. Rev. 43*: 209-236, 470-492.

Bastian HC (1880): *The Brain as an Organ of the Mind*, London, Kegan Paul.

Benton AL (1977): The Amusias. In: Critchley M & Henson RA, eds., *Music and the Brain*, London, Heinemann, Med. Books Lt., pp. 378-397.

Benton AL & Joynt RJ (1960): Early descriptions of aphasia. *Arch Neurol. 3*:205-222.

Bergson HL (1896): *Matière et Mémoire*, Paris.

Bever TG & Chiarello RD (1974): Cerebral dominance in musicians and nonmusicians. *Science 185*: 537-539.

Bogen JE & Gordon HW (1971): Musical tests for functional lateralization with intracarotid amobarbital. *Nature 230*: 524-526.

Bouillaud, JB (1865): Sur la faculté du langage articulé. *Arch. gén. méd. 1*: 575-579.

Breasted, JH (1930): *The Edwin Smith Surgical Papyrus*. Chicago, University of Chicago Press.

Broca PP (1861): Perte de la parole, ramollissement chronique et destruction partielle du lobe antérieur gauche (Sur le siège de la faculté du langage). *Bull. Soc. d'Anthrop. II*: 235-238.

Broca PP (1863): Remarques sur le siège, le diagnostic et la nature dé l'aphémie. *Bull. Soc. Anat*, 2e sér., t. VIII, 379-385, 393-399 Broca PP (1866): Du siège de la faculté du langage articulé dans l'hémisphère gauche du cerveau. *Bull. Soc. d'Anthrop.* 2e sér, t.1. 373-382.

Chaussier FB (1807): *Exposition sommaire de la structure et des différentes parties de l'encéphale ou cerveau*, Paris, Barrois, pp. 36-37.

Cherry CL (1979): The Southern retreat, Thomas Hodgkin and Achille-Louis Foville. *Med. Hist. 23*: 314-324.

Clarke E & O'Malley CD (1996): *The Human Brain and Spinal Cord*, San Francisco, Norman, p. 12, p. 386, pp 390-391.

Dandy W (1933): Physiological studies following extirpation of the right cerebral hemisphere in man. *Bull. Johns Hopkins Hosp. 53*: 31-51.

Edgren JG (1895): Amusie (musikalische Aphasie). *D. Ztschr. Nervenheilk. 6*: 1-64. q. by BMJ II: 1441-1442.

Falret J (1864): Trouble du language et de la mémorie des mots dans les affections céréberales (aphémie, aphasie, alalie, amnésie verbale). *Arch. gén. de méd. Paris, sér. 6*:243-276.

Falret J (1864): Trouble de langage et de las mémoire des mots dans les affections cérébrales (aphémie, aphasie, alalie, amnésie verbale. *Arch. gén. dé méd*. Paris, G.s III.

Ferrier D (1876): *The Functions of the Brain*, London, Smith, Elder, p. 171

Finger S (1994): *Origins of Neuroscience: A History of Explorations into Brain Function*, New York, Oxford Univ. Press, pp. 126-131

Finkelnburg KM (1870): Asymbolie und Aphasie. *Berlin. Klin. Wchnschr. 1*: 449-450, 460-462

Foville AL (1844): *Traité complet de l'anatomie, de la physiologie et de la pathologie du système nerveux cérébro-spinal*, Paris, Fortin, Masson et Cie.

Freud S. (1953): *Zur Auffassung der Aphasien*, ((1891) *On Aphasia, A Critical Study*:) New York, Internat'l Univ. Press, p. 102.

Goldstein K (1970): Carl Wernicke (1848-1904). In: Haymaker W & Schiller F. *The Founders of Neurology*, Springfield, Thomas, pp. 531-535.

Gowers WR (1875): On a case of simultaneous embolism of central, retinal and middle cerebral arteries. *Lancet 2*: 794-796.

Gratiolet LP (1854) *Mémoire sur les plis cérébraux de l'homme et des primates*. Paris Baillière.

Head H (1926): *Aphasia and Kindred Disorders of Speech*. Cambridge, Univ. Press. vol. 1, p. 140.

Heschl RL (1878): *Über die vordere quere Schläfenwindung des menschlichen Grosshirns*, Vienna, Braumüller.

Kimura D (1967): Functional assymmetry of the brain in dichotic listening. *Cortex 3*: 163-187.

Knoblauch A (1888): Über Störungen der musikalischen Leistungs fähigkeit infolge von Gehirnläsionen *Deut. Arch. Klin. Med. 43*: 331-352.

Luria AR, Tsvetkova LS & Futer DS (1965): Aphasia in a composer. *J. Neuro Sci. 2*: 288.

Marie P (1906): Révision de la question de l'aphasie *Semaine méd 1906*: 241-247, 493-500, 560-571.

Meynert T (1866): Ein Fall von Sprachstörung, anatomisch begründet. *Med Jahrbücher 12*: 152-187.

Milner B (1962): Laterality effects in audition. In: Mountcastle VB: *Interhemispheric Relations and Cerebral Dominance*, Baltimore, Johns Hopkins, pp. 177-195.

Mott FW (1907): Bilateral lesion of the auditory cortical centre. Complete deafness and aphasia, *Brit. Med. J, 2*: 310-315.

Ombredane A (1951): *L'Aphasie et l'Élaboration de la Pensée Explicie*, Paris, Presses Universitaires de France, p. 40, 107-108.

Penfield W & Rasmussen T (1955): *The Cerebral Cortex of Man. Clinical Study of Localization*, New York, Macmillan, p. 171.

Pötzl O & Uiberall H (1937): Zur Pathologie der Amusie. *Wien. Klin. Wschr. 50*: 770-796.

Reil JC (1796) Exercitationum anatomicarum fasciculus primus. De structura nervorum. Halle, Venalis (1796): Untersuchungen über der Bau des grossen Gehirns im Menschen (1809). *Arch Physiol. Halle 9*: 136-146.

Ritti A (1878): Achille Foville (Nécrologie). *Gazette Hebdomadaire de Méd et de Chir*. 2nd ser. XV: 499-500.

Rolando L (1809): *Saggio sopra le Vera Struttura del Cervello dell'Uomo et degli Animali e sopra le Funzioni del Sistema Nervoso*. Sassari, Stamperia de S.S.R.M. Privilegiata.

Schäfer EA (1888a): Experiments on special sense localizations in the cortex cerebri of the monkey. *Brain 10*: 362-380.

Schäfer EA (1888b): On the functions of the temporal and occipital lobes. A reply to Dr. Ferrier *Brain 11*: 145-166.

Seitelberger F (1997): Theodor Meynert (1833-1892), pioneer and visionary of brain research. *J Hist. Neuro Sci 6*: 264-274.

Sparks R, Helm N & Albert M (1974): Aphasia rehabilitation resulting from melodic intonation therapy. *Cortex 10*: 303-316.

Varolius C (1573): *Anatomia de resolutione corporis humani libri IV*, Patavi Pret, A. Meiettos, p. 131.

Varolius C (1591): *De nervis opticis, nonnullisque aliis praeter communem opinionem in humani capite observatis epistola*, Frankfurt, Iannem Welchelum et Petrum Fischerum.

Vicq-d'Azyr F (1786): *Traité d'Anatomie et de Physiologie Vol 1, Anatomie et Physiologie du Cerveau*, Paris, FA Didot.

Weisenburg T & McBride K (1937): *Aphasia*, New York, Commonwealth Fund, p. 468.

Wernicke C (1874)L *Der aphasische Symptomen-Complex*, Breslau, Kohn & Weigert.

Willis T (1983): The Anatomy of the Brain and Nerves. In Feindel, W., ed., *The Classics of Neurology and Neurosurgery*, Birmingham, Chap X. p. 91.

Woolsey CN & Walzl EM (1942): Topical projection of nerve fibers from local regions of the cochlea to the cerebral cortex of the cat. *Johns Hopkins Hosp. Bull. 7*: 315-349.