PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Preface to The measurement of brain activity. A Theme organized and edited by A. Howseman and S. Zeki

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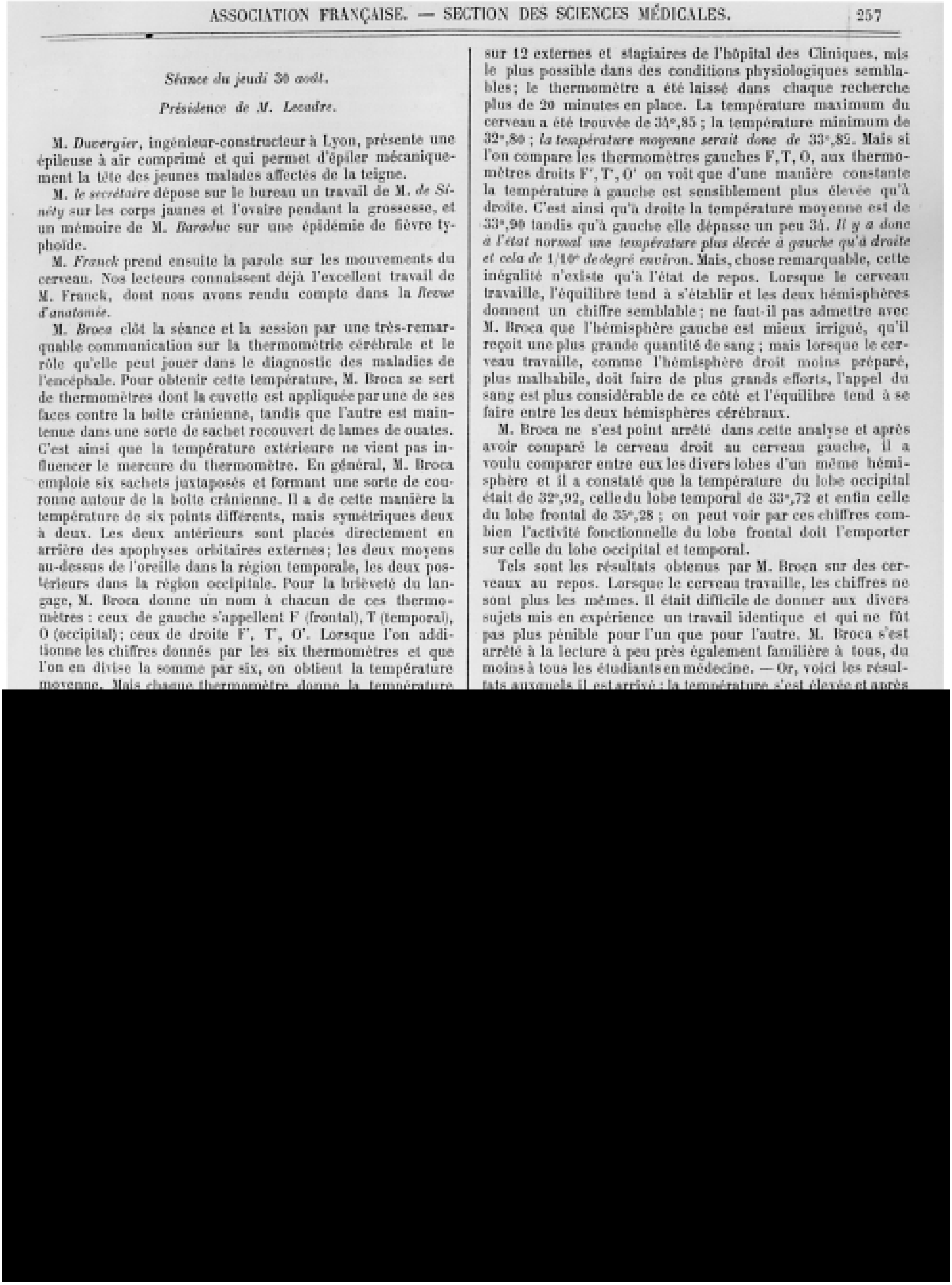
Preface

Important insights and advances in scientific discovery are often driven by the development of new technology and the advent of new measurement techniques. Cognitive neuroscience is no different to other branches of science in its reliance on such developments to accelerate its progress. It is indeed often difficult to pursue new insights unless the technology to exploit them is available. An apt example concerns the insight into the relationship between regional cortical blood flow and cortical activity, made by Broca and by Roy & Sherrington in the last century, in articles reproduced in figures 1 and 2 here. It was, however, to take nearly one century before these insights could be put to use. But, in recent years there has been an unprecedented surge in the range of tools available to measure activity in the brain. These techniques range from the invasive, with their incumbent problems, to the entirely non-invasive, which can be used on human volunteers. The multitude of different techniques reflects the fact that each have their own particular advantages. All methods also have their limitations, be they of convenience, expense, invasiveness, accuracy, sensitivity, and spatial and temporal resolution.

Brain imaging methods, which simultaneously localize multiple signal sources, have perhaps the highest profile of all the techniques which are used to measure brain activity. Collectively, the application of these techniques has become known as 'brain mapping'. However, the existence of such methods does not in itself guarantee success in the advancement of our knowledge about how the brain actually works. A map is only as good as its legend and the legend can only be truly useful if the meaning of what it represents is clearly understood. The magnitude of the contribution of imaging methods to fundamental neuroscientific issues is both clear—witness the demonstration of the principle of functional specialization in human visual cortex—and yet unclear—how much will imaging methods tell us about how prefrontal cortex performs the complex tasks which make the human brain so unique? Blessed with the richness of the information which the brain imaging methods provide it is perhaps easy to forget the value of other non-mapping techniques.

Recently, multidisciplinary centres for the measurement of brain activity have been set up which incorporate many different methodologies. These centres allow the fusion of technological expertise, clinical and basic neuroscience, and the development and application of statistical and processing methods. To do justice to the vast amount of research which is currently being done in these fields in a single issue of this journal is an impossible task. There are indeed several excellent textbooks covering the methods used in functional neuroimaging. In inviting contributions for this special issue of the Philosophical Transactions on *The measurement of brain activity* we have simply tried to cover a breadth of subjects which are currently of great interest and are undergoing rapid development. We have deliberately left out some topics which have been covered extensively elsewhere or have been the subject of recent review. This issue covers both technique development and the application of those techniques, in particular in fields of non-sensory, higher-order, cognitive neuroscience.

The opening papers (Gevins *et al.*; Makeig *et al.*; Hari & Forss) look at the measurement of electrical and magnetic potentials in the brain, techniques which have somewhat limited spatial characteristics but offer excellent temporal resolution. In the contributions from Magistretti & Pellerin and Rothman *et al.*, the relationship between functional imaging and the underlying physiological events which occur as neuronal firing increases is explored. An understanding of these relationships is important so that functional imaging data may be interpreted in relation to cellular neurobiology. Increasingly, functional magnetic resonance imaging (fMRI) is becoming the method of choice in functional neuroimaging. Its non-invasiveness and good spatial and temporal resolution are seeing it supersede positron emission tomography in many cases. The techniques used in fMRI are discussed in the papers of Howseman & Bowtell, Ugurbil *et al.* and Josephs & Henson. Transcranial magnetic stimulation (TMS) is a technique in which a rapid pulse of a localized magnetic field is applied to transiently perturb the neural circuitry of the cortex. The application of this method to measurements of brain activity is described by Pascual-Leone *et al.* Underpinning functional brain imaging is the statistical treatment of the data. In the papers by Petersson *et al.* the extent of the inference which can be drawn from functional imaging experiments, and their limitations, are discussed. The next group of papers (Kosslyn; Tomberg & Desmedt; Wagner *et al.*; Mesulam) cover the application of brain measurement techniques to the study of imagination, consciousness, memory and attention. Next, Ingvar describes how the experience of pain is being studied with functional imaging. In the contribution from Fu & McGuire the use of functional imaging in psychiatry is explored both in terms of how imaging methods can contribute to an understanding of the processes of mental illness and also, and most importantly, to what extent functional imaging will play a role in the clinical management of mental health patients. Finally, in a paper by Zeki & Bartels, the worth of using clinical observation in conjunction with the new measurement techniques is emphasized with reference to the example of colour vision.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Séance du jeudi 30 août.

Présidence de M. Lecadre.

M. *Duvergier*, ingénieur-constructeur à Lyon, présente une épileuse à air comprimé et qui permet d'épiler mécaniquement la tête des jeunes malades affectés de la teigne.

M. *le secrétaire* dépose sur le bureau un travail de M. *de Sinéty* sur les corps jaunes et l'ovaire pendant la grossesse, et un mémoire de M. *Baraduc* sur une épidémie de fièvre typhoïde.

M. *Franck* prend ensuite la parole sur les mouvements du cerveau. Nos lecteurs connaissent déjà l'excellent travail de M. Franck, dont nous avons rendu compte dans la *Revue d'anatomie.*

M. *Broca* clôt la séance et la session par une très-remarquable communication sur la thermométrie cérébrale et le rôle qu'elle peut jouer dans le diagnostic des maladies de l'encéphale. Pour obtenir cette température, M. Broca se sert de thermomètres dont la cuvette est appliquée par une de ses faces contre la boîte crânienne, tandis que l'autre est maintenue dans une sorte de sachet recouvert de lames de ouates. C'est ainsi que la température extérieure ne vient pas influencer le mercure du thermomètre. En général, M. Broca emploie six sachets juxtaposés et formant une sorte de couronne autour de la boîte crânienne. Il a de cette manière la température de six points différents, mais symétriques deux à deux. Les deux antérieurs sont placés directement en arrière des apophyses orbitaires externes; les deux moyens au-dessus de l'oreille dans la région temporale, les deux postérieurs dans la région occipitale. Pour la brièveté du langage, M. Broca donne un nom à chacun de ces thermomètres : ceux de gauche s'appellent F (frontal), T (temporal), O (occipital); ceux de droite F', T', O'. Lorsque l'on additionne les chiffres donnés par les six thermomètres et que l'on en divise la somme par six, on obtient la température

sur 12 externes et stagiaires de l'hôpital des Cliniques, mis le plus possible dans des conditions physiologiques semblables; le thermomètre a été laissé dans chaque recherche plus de 20 minutes en place. La température maximum du cerveau a été trouvée de 34°,85 ; la température minimum de 32°,80 ; *la température moyenne serait donc de* 33°,82. Mais si l'on compare les thermomètres gauches F, T, O, aux thermomètres droits F', T', O' on voit que d'une manière constante la température à gauche est sensiblement plus élevée qu'à droite. C'est ainsi qu'à droite la température moyenne est de 33°,90 tandis qu'à gauche elle dépasse un peu 34. *Il y a donc à l'état normal une température plus élevée à gauche qu'à droite et cela de* 1/10*e de degré environ.* Mais, chose remarquable, cette inégalité n'existe qu'à l'état de repos. Lorsque le cerveau travaille, l'équilibre tend à s'établir et les deux hémisphères donnent un chiffre semblable; ne faut-il pas admettre avec M. Broca que l'hémisphère gauche est mieux irrigué, qu'il reçoit une plus grande quantité de sang ; mais lorsque le cerveau travaille, comme l'hémisphère droit moins préparé, plus malhabile, doit faire de plus grands efforts, l'appel du sang est plus considérable de ce côté et l'équilibre tend à se faire entre les deux hémisphères cérébraux.

M. Broca ne s'est point arrêté dans cette analyse et après avoir comparé le cerveau droit au cerveau gauche, il a voulu comparer entre eux les divers lobes d'un même hémisphère et il a constaté que la température du lobe occipital était de 32°,92, celle du lobe temporal de 33°,72 et enfin celle du lobe frontal de 35°,28 ; on peut voir par ces chiffres combien l'activité fonctionnelle du lobe frontal doit l'emporter sur celle du lobe occipital et temporal.

Tels sont les résultats obtenus par M. Broca sur des cerveaux au repos. Lorsque le cerveau travaille, les chiffres ne sont plus les mêmes. Il était difficile de donner aux divers sujets mis en expérience un travail identique et qui ne fût pas plus pénible pour l'un que pour l'autre. M. Broca s'est arrêté à la lecture à peu près également familière à tous, du moins à tous les étudiants en médecine. — Or, voici les résul-

[redacted]

Figure 1. The first page of P. Broca's paper 'On the temperature of the brain and its role in diagnosing some cerebral maladies' (*Revue Scientifique* 1878, vol. XI, p. 257). (Science Museum/Science & Society Picture Library.)

ON THE REGULATION OF THE BLOOD-SUPPLY OF THE BRAIN. BY C. S. ROY, M.D., F.R.S., *Professor of Pathology, University of Cambridge*, AND C. S. SHERRINGTON, M.B., M.A., *Fellow of Gonville and Caius College. Lecturer on Physiology in the School of St Thomas's Hospital, London.* Plates II., III. and IV.

From the Cambridge Pathological Laboratory.

ONE marked characteristic of the literature dealing with the cerebral circulation is, we think, the contradictory nature of the results which have been obtained by different investigators.

There is no reason, we imagine, for doubting that the cause of these discrepancies is to be found in the great difficulty of avoiding the sources of error which plentifully surround the subject, and in overcoming certain technical difficulties which we shall presently have to refer to. The ease with which one can obtain results upon certain points, on taking up the subject, is itself, we believe, apt to make the inquirer careless in controlling sources of error, which, it may be noted, are some of them not at first sight obvious. We must on this account say more about the technology of our subject than would be necessary were the subject a simpler one.

Methods employed by other observers.

In order that the bearing of our method may be understood, we think it well to refer to some of the other modes by which different observers have investigated the cerebral circulation. Some observers have simply inspected the exposed pia mater, as was done by Haller[1]. In most, if not all, of these experiments there appears to have been no simultaneous record taken of the arterial or venous pressure. That such a method, so rough in itself, could easily lead to untrustworthy results—giving as it does no means of distinguishing active changes in calibre of the cerebral vessels from passive variations of their width produced by changes in the arterial and venous pressures—will, we think, be readily admitted.

[1] *Opera Minora.* Tom. I. p. 131.

Figure 2. The opening of C. S. Roy and C. S. Sherrington's paper on cerebral blood supply, published in the *Journal of Physiology* (1890, vol. XI, p. 85). (This reproduction comes from a lithographic reprint of 1952, held in the Library of the Royal Society of Medicine, and reproduced with their kind permission and that of the Physiological Society.)

No doubt there are many important areas which have been omitted from this edition. However, our hope is that the papers included here provide a useful collection at this time and in particular give a sense of the multidisciplinary nature of this research. The challenges ahead in making measurements of activity in the human brain and using these to further our understanding of how the brain works, will surely depend on how successful we are in integrating the many disparate elements of this field.

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