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ON DILATATION OF THE PUPIL FROM STIMULATION OF THE CORTEX CEREBRI. By J. HERBERT PARSONS, B.Sc., F.R.C.S. (Two Figures in Text.)

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ON DILATATION OF THE PUPIL FROM STIMULATION OF THE CORTEX CEREBRI.

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CONTENTS.

I. History.

Several previous observers have noticed dilatation of the pupil following excitation of various parts of the cerebral cortex.

Bochefontaine[1] (1875) was the first to record the fact as the result of experiments upon dogs. He showed that it might occur when the animals were curarised.

Luciani and Tamburini[2] observed both dilatation and constriction in some of their experiments.

Ferrier[3] confirmed these results, and added further details; thus, indicating the spots stimulated by numbers, he makes the following statements:—In monkeys, "(12) Including the posterior half or two-thirds of the superior and middle frontal convolutions, the eyes widely open, the pupils dilate, and head and eyes turn to the opposite side." "(13) and (13*a*) On the anterior and posterior limb of the angular gyrus respectively the eyes move to the opposite side......usually also the pupils become contracted." "(14) On the superior temporosphenoidal convolution pricking of the opposite ear, head and eyes turn to the opposite side, pupils dilate widely." In dogs, "(7) On the frontal division of the second[1] external convolution (coronal convolution)......the movements of the eyeballs I have found to be divergent, associated with contraction of the pupils." "(12) On the precrucial division of the sigmoid gyrus the eyes widely opened with dilatation of the pupils.......In one or two instances I have seen the eyeballs converge, but in all cases the pupils were dilated." "(13) On the parietal and posterior division of the second[1] external convolution movement of the eyeballs to the opposite side......the pupils occasionally contract." Similar results were obtained upon jackals, equivocal results on rabbits. In cats he only occasionally obtained constriction, but does not state that he ever obtained dilatation. In pigeons the most constant effect of any was an intense constriction of the opposite pupil on stimulating the middle of the convexity of the hemisphere.

Horsley and Schäfer[(4)] obtained hemiplegia, accompanied by great dilatation of the right pupil and constriction of the left, in a monkey in which the anterior part of the right marginal convolution and almost the whole of the motor area had been removed.

Schäfer[(5)], in exciting the visual centre in monkeys, besides ocular movements, obtained movements of the eyelids, etc., which, he states, "have not been constant in my experiments, nor have the changes in the pupils which are sometimes observed accompanying the movements of the eyes. I have occasionally obtained from stimulation on or near the quadrate lobule marked constriction of the pupils.......More usually, however, the movements whatever the part stimulated, are accompanied by dilatation of the pupil."

Beevor and Horsley[(6)] state: "In the vast majority of instances there was no movement of the pupils; when it occurred dilatation was always noted. This dilatation of the pupils exists simply in association with turning of the head and eyes to the opposite side. It appeared to be represented most round the horizontal limb of the precentral sulcus, but we did not observe it many times." They[(7)] also obtained dilatation of the pupils on stimulation of the fore part of the internal capsule. In the orang-outang they[(8)] expressly state that there was no dilatation of the pupils from stimulating the brain anterior to the precentral sulcus.

François-Franck and Pitres[(9)] obtained dilatation of the pupil in the dog from excitation of the anterior branch of the sigmoid, and the

[1] The third convolution of most authors.

anterior branch of the suprasylvian convolutions; and in the cat from the anterior part of the suprasylvian region and the adjacent part of the third external convolution. The effect is obtained more slowly from stimulating the cortex than from direct stimulation of the cervical sympathetic nerve, but the latent period is shortened, and more nearly approaches that of the cervical sympathetic, if the oculo-motor nerve has been previously divided. Franck concludes from this that the effect is of the nature of a dilemma, but this view cannot be considered proved in the absence of accurate measurements of the respective latent periods. Constriction of the pupils was occasionally obtained in the dog from stimulation of the median part of the 3rd external convolution —accompanied by widening of the palpebral aperture without projection of the eyes. Stronger stimulus invariably led to dilatation, which rapidly followed the transitory constriction. The stimulation of the corresponding fibres of the corona radiata invariably caused constriction, never dilatation nor epileptoid convulsions. Franck and Pitres confirm Beevor and Horsley in obtaining dilatation from excitation of certain parts of the internal capsule.

Bechterew and Mislawski [10], in investigating the centres for the secretion of tears, obtained also the usual effects of stimulation of the cervical sympathetic (dilatation of the pupil, retraction of the nictitating membrane, &c.) from excitation of the inner parts of the anterior and posterior divisions of the sigmoid gyrus in the dog.

An extremely interesting observation is recorded by Sherrington [11]. In bringing physiological experiment to bear upon current theories of the emotions, he performed "appropriate spinal and vagal transection" in the dog to eliminate "the sensation of all the viscera and muscles below the shoulder." He says:—"the eyes were well opened, and the pupil distinctly dilated in the paroxysm of anger. Since the brain had been by the transection shut out from discharging impulses *viâ* the cervical sympathetic the dilatation of the pupil must have occurred by inhibition of the action of the oculo-motor centre."

II. Method.

Experiments have been performed upon 2 dogs, 28 cats and 1 monkey. The animals were anæsthetised with A.C.E. mixture in a few of the earlier experiments, but with ether only in the majority. They were completely anæsthetised and insensitive to pain throughout the experiments. When the animal is spoken of as being 'lightly anæsthetised,' the test of the condition was the excitability of the motor areas of the cortex to stimuli of moderate severity, as shown by movements of the limbs of the contralateral side. 'Epileptoid convulsions' (called 'struggles' in a preliminary communication [12]) is the term used to express the violent general movements which often follow stimulation of the motor area after exposure of the brain to air, or prolonged or frequently repeated excitation. It is well known that under these conditions the cortical cells become more excitable, the condition being quite compatible with complete anæsthesia.

The cervical sympathetics were either cut or isolated on one or both sides. In the dog the vago-sympathetic was treated as a whole. This was sometimes done also in the cat to ensure the complete division of all sympathetic fibres. In some experiments the superior cervical ganglion was extirpated to eliminate any dilator fibres which might reach the ganglion by any hitherto unknown course. Section of the sympathetic was usually followed by a distinct moderate constriction of the corresponding pupil, but this was certainly not invariably the case. Absence of a tonic dilator influence is probably under such circumstances due to the condition of anæsthesia of the animal.

A cannula, connected with a Woulff's bottle containing the anæsthetic, was usually inserted into the trachea, as by this means the eyes were left quite free for observation, and the amount of anæsthetic and air could be accurately modified by means of stopcocks. Where drugs were injected, it was through a cannula in the external jugular vein.

The skull was then trephined over the area which it was desired to excite. The profuse bleeding from the skull was controlled by the soft wax, introduced by Professor Horsley. The dura mater was incised crucially. The brain was kept warm and moist by a pad of cotton-wool soaked in warm saline solution, frequently renewed.

For excitation, a du Bois-Reymond induction coil was used, the shock being just perceptible when the electrodes were placed upon the tongue; but the current was not always constant, and occasionally the coil had to be pushed up to obtain the original strength of stimulus.

In order to give a good view of the pupils, the eyelids were generally removed, if it was not specially desired to observe their behaviour. They were not removed in the experiment upon the monkey. The state of the pupil I determined by inspection.

It is easy in the cat's eye to direct one's attention to the horizontal meridian. The constricted pupil being a vertical slit, the distance from the centre to the periphery can be divided into four imaginary parts, the pupil being said to be a quarter, a half, three-quarters, or fully dilated. This method of stating the results has been adopted in some of the protocols.

The amount of light falling upon the eyes was usually fairly constant throughout the experiment, being diffuse London sunlight. In a few experiments performed on dark winter afternoons, a powerful (16-candle) electric light, placed about 3 feet off in the middle line in front of the animal's head was used. It is only important to keep the light fairly constant.

III. Localisation.

As will be seen from the historical *résumé*, both dilatation and constriction of the pupils have been described as results of cortical stimulation. The former is easy to demonstrate, the latter much more difficult. Most observers have regarded the effects as inconstant, and but little attention has been specially directed to them. Thus Ferrier includes dilatation of the pupil with salivation from the submaxillary gland, changes in pulse and blood-pressure, and "other indications of general reverberation throughout the organism." He regards them as "merely complications, and not as results of localised cortical stimulation." On the other hand, Bechterew and Mislawski conclude that "stimulation of the given regions of the cortex and of the optic thalmi has hit off the central endings (Verlängerungen) of the cervical sympathetic"; and that "the chief reflex centre for secretion of tears lies in the optic thalmi, and that there too are found the central tracts of the cervical sympathetic, their prolongations (Fortsetzungen) being continued thence to the cortex." François-Franck is careful to distinguish between two causes of dilatation of the pupil resulting from cortical excitation. One is a special and localised effect following stimulation of definite foci of the cortex, and also obtained from excitation of the underlying fibres of the corona radiata and internal capsule. The other accompanies epileptoid convulsions resulting from the stimulation of any and every part of the motor areas, and is never obtained from the underlying white matter, which does not induce the epileptic state. To the latter he attributes the dilatation after administration of curare, which was observed by Bochefontaine. He perhaps lays too great stress upon this as a fundamental distinction, for it applies equally to other motor effects induced through the cortex.

I have not paid much attention to any movements other than those of the eyes and pupils. Dilatation of the pupils is often obtained without any movement of the eyes or body. I have usually found that a slightly stronger stimulus is necessary to evoke it than that which is required to produce movement from excitation of the arm or leg areas: or the same strength of stimulus may suffice if the animal be slightly less under the influence of the anæsthetic.

(*a*) *Cat.* In the cat dilatation of the pupil can be obtained from a considerable area in the neighbourhood of the crucial sulcus and from a considerable area of the occipital region. As the result of many experiments it is found that the mesial surface of the hemisphere near the crucial sulcus (prorean and pre-splenial convolutions[1]) gives the most marked effect, but I have also found that the anterior part of the third or median convolution (coronal or anterior supra-sylvian, corresponding with Ferrier's[7] in the dog) gives a very constant effect. In one or two instances there has been a transitory constriction of the pupils before the dilatation from this area. Ferrier obtained constriction of the pupils and divergence of the eyeballs from this spot, but I have not observed the latter effect in the cat.

In the occipital region, what may be called the focal spot is in the posterior part of the third or median convolution (posterior supra-sylvian convolution, corresponding with Ferrier's (13)). I have not observed any constriction of the pupil here, as described by him. François-Franck, however, obtained a transitory constriction from this spot, followed by dilatation, exactly like that which I describe for the coronal gyrus. It is therefore probable that there are foci for pupil-constriction both in the frontal and occipital areas, but that they are masked by the dilator effects, which are so much more readily produced. One may compare with this the greater representation of lateral eye-movements over any other eye-movements in the cortex[13].

The following is the protocol of a typical experiment.

Exp. XXVII. Large Cat. Ether. Both cervical sympathetics divided, both vagi intact. Left frontal region exposed.

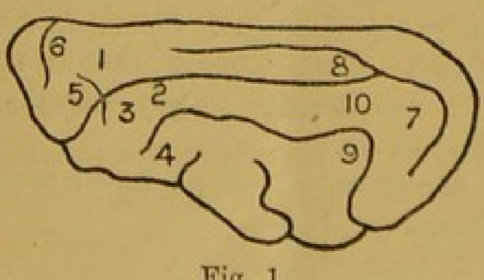

Fig. 1.

[1] For the nomenclature, see Langley. This *Journal*, IV. p. 248, 1882-3.

P.M.

2.45 Coil at 10, just felt by tongue. Stimulate (1) = dilatation of both pupils—no movements.

2.47 Pupils equal, ½ dilated: stimulate (1) = epileptoid convulsions; both dilate to nearly ¾.

2.52 Stimulate (2) = eyes straight forward—dilate.

2.53 Pupils equal, ¼: stimulate (1) = pupils dilate to ½, then eyes straight.

2.54 Pupils ¼: stimulate (3) = dilate to ½, the eyes straight. Stimulate (2) = eyes straight, then pupils dilate to ½.

2.55 Pupils ¼: stimulate (1) = R. leg moved, pupils to ½.

2.56 Ditto.

2.57 Pupils ¼: stimulate (4) = epileptoid convulsion, pupils to ¾.

3.0 Repeat = nil, deep anæsthesia. Less ether.

3.6 Pupils ¼: stimulate (5) = R. shoulder moved, pupils to ½.

3.10 Pupils ¼: stimulate (6) = nil; stimulate (1) = pupils to ¾.

3.12 Pupils ¼: stimulate inner surface of hemisphere near (1) = epileptoid convulsion, pupils to >¾.

3.15 Repeat = eyes up, pupils to ½.

3.20 Coil 9½. Repeat = pupils to ¾, no body movements. Pupils ¼: stimulate (6) = scarcely appreciable dilatation; stimulate (4) = movements of R. ear, pupils nil. Occipital lobe exposed.

3.30 Pupils ¼: stimulate (7) = eyes up and forward, pupils to ½.

3.33 Repeat = eyes up and forward, pupils to >½.

3.35 Pupils ¼, eyes divergent, directed somewhat down and out; stimulate (8) = nil; stimulate (9) = nil; stimulate (10) = eyes straight, pupils to ½.

3.40 Pupils ¼: stimulate (1) = R. leg moved, pupils to ½.

(*b*) *Dog.* The areas are very much the same in the dog as in the cat, but I obtained a very marked effect from the precrucial gyrus in the area marked (12) by Ferrier. I did not observe any convergence of the eyeballs in this experiment.

(*c*) *Monkey.* The monkey is much the easiest animal to work with and gives very definite results.

Exp. XXX. Rhesus. Ether. Both sympathetics divided. L. side of cortex exposed.

A.M.

11.40 Coil 11·9, just felt by tip of tongue. Stimulate (1) = eyes down and to R., pupils dilate widely. Fresh battery. Coil at 12·5, just felt by tongue.

11.46 Stimulate (1) = nil; repeat = nil. Deeply anæsthetised, less ether. 11.48 Repeat = nil. Coil at 12.

11.49 Stimulate (1) = no movement of eyes, pupils dilate slightly.

11.50 Repeat = no movement, pupils to ¾.

11.51 Stimulate (2) = R. foot moved, pupils nil.

11.52 Stimulate (3) = R. arm moved, pupils nil. Stimulate (4) = R. arm moved vigorously, pupils nil.

A.M.

11.53 Stimulate (1) = eyes down and to R., pupils dilate. 11.54 Repeat = ditto.

11.55 Repeat = ditto.

11.57 Repeat = ditto, then epileptoid convulsion with wide dilatation of pupils.

11.59 Stimulate (1) = eyes to R., pupils dilate. Frontal bone removed farther forwards.

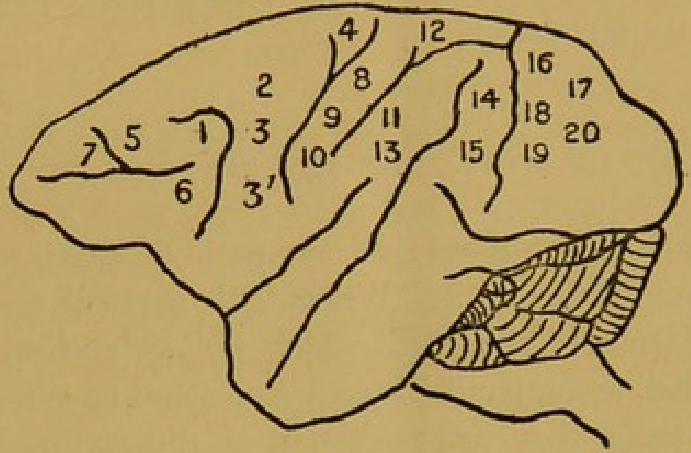

Fig. 2.

P.M.

12.7 Stimulate (6) = L. eye up and to R., pupils nil.

12.8 Stimulate (5) = eyes straight, marked dilatation.

12.9 Stimulate (6) = both up and to R., L. moves much more than R., pupils dilate.

12.10 Stimulate (1) = eyes to R., pupils dilate.

12.11 Stimulate (5) = eyes to R. and slightly up, pupils dilate.

12.12 Stimulate (6) = eyes well up and to R., pupils dilate.

12.13 Stimulate (1) = eyes to R., marked dilatation.

12.14 Stimulate (5) = eyes to R., marked dilatation.

12.15 Stimulate (6) = eyes up and to R., less dilatation.

12.16 Stimulate (7) = eyes straight (only slight movement), pupils dilate; epileptoid fit, marked dilatation.

12.18 Stimulate (2) = R. foot moves vigorously, pupils nil.

12.19 Stimulate (3) = R. arm moves vigorously, pupils nil.

12.20 Stimulate (3′) = R. side of face moves, R. orbicularis palpebrarum contracts, pupils nil. Skull removed farther back.

12.22 Stimulate (8), (9), (10) successively = nil: then epileptoid fit, wide dilatation.

12.25 Exactly same sequence as 12.22. Stimulate (4) = R. arm moves vigorously, pupils nil. Stimulate along fissure of Rolando = nil. Stimulate along intraparietal fissure = nil.

12.27 Stimulate (11) = nil: ditto (12). Skull removed still farther back.

12.30 Stimulate (13), (14), (15), (16) successively = nil, then epileptoid fit and wide dilatation.

12.35 Skull removed to lambdoid suture.

12.40 Stimulate (14), (15), (16), (17), (18), (19) = nil. Stimulus not perceptible to tongue. Coil pushed up to 11. Stimulate (16) = eyes slightly down and to R., slight dilatation. Stimulate (17) = ditto. Stimulate (18) = eyes to R., slight dilatation. Rather deep anæsthesia. Stimulate (16), (17) = same result, then epileptoid fit and wide dilatation.

P.M.
1.1 Pupils rather widely dilated: very small dose of A.C.E. on = pupils contract slightly. Stimulate (16) = nil, (17) = eyes to R. and slight dilatation. Stimulate (18) = eyes to R. and slight dilatation. Stimulate (16), (18) = ditto, (19), (20) = nil.

The comparatively small result from the occipital lobe is probably due to the long duration of the experiment.

IV. Effect of section of the cervical sympathetic.

Previous section of the cervical sympathetic diminishes the effect but by no means abolishes it. When both cervical sympathetics are intact, the dilatation of the pupil which follows cortical excitation is, when well marked, accompanied by all the usual effects of stimulation of the nerves themselves, viz., retraction of the nictitating membrane, widening of the palpebral aperture and projection of the eyeball: to these Bechterew and Mislawski add secretion of the lacrymal gland, but this I am unable definitely to confirm. All these effects are abolished by previous section of the sympathetics except the dilatation of the pupils, and this is diminished. Whereas, when the nerves are intact, full dilatation of the pupils may occur, especially during epileptoid convulsions, after they are divided the pupils rarely become more than three-quarters dilated. The effect is very well seen if one nerve is divided, the other being intact. In this case the two pupils move synchronously and apparently to the same extent, except that they start unequal, the one on the divided side being the smaller. The following remark of François-Franck is therefore certainly incorrect. "It is only in experiments in which the sympathetic has been divided on one side that the pupillary dilatation is unilateral." He certainly admits a slight degree of dilatation, which he attributes to dilator fibres running another course, probably in the trigeminal. I have eliminated this possibility by dividing the V. nerve intracranially, and still obtaining the undiminished effect. (See Appendix, Exp. XXIX.) To eliminate the possibility of other dilator fibres reaching the superior cervical ganglion, I have, as already stated, extirpated it. The pupil on the side from which the ganglion was removed was slightly but appreciably smaller than on the side on which the vago-sympathetic was divided. (See Appendix, Exp. XIX.)

V. Effect of section of the III. nerve.

Section of the III. nerve intracranially after previous division of the cervical sympathetic causes the pupil to become immobile, about three-quarters dilated, and stimulation of no part of the cortex has any effect upon it.

VI. Effect of section of the corpus callosum.

Complete section of the corpus callosum has no effect upon the result of stimulating the cortex. The bilateral effect is therefore not due to the stimulus acting through the opposite cortical areas, but to its acting upon lower centres, but whether the optic thalami or the superior corpora quadrigemina I am not prepared to say, but probably the latter.

VII. Effect of stimulation of the corona radiata and internal capsule.

Stimulation of the anterior and posterior parts of the corona radiata and internal capsule containing the fibres derived from the cells of the frontal and occipital areas mentioned leads to bilateral dilatation of the pupils. I have generally found a stronger excitation necessary, but this may be due to the fact that stimulation took place at the end of prolonged experiments. In one case (App., Exp. XXIX.), I obtained a very marked constriction of the pupils, with strong convergence of the eyeballs from stimulation of the posterior part of the internal capsule.

VIII. Criticism and conclusions.

The only point in these results which requires further consideration is the mechanism by means of which dilatation of the pupil can occur in the absence of the usual dilator tract. Two explanations offer themselves, viz., inhibition of tonic action of the III. nerves and a dilatation brought about by vascular changes in the iris. Sherrington, in the interesting experiments recorded, does not hesitate to accept the first explanation. It is said that after the optic nerves have been cut, dilatation is not obtained upon section of the III. nerve, and hence a tonic action of the III. nerve has sometimes been denied. There can be no question, however, that it exists when the optic nerves are intact, as in these experiments.

The immobility which follows section of both the III. and the sympathetic is strong evidence in favour of the inhibition theory. It must be noted, however, that the blood-pressure was probably very subnormal at this stage of the experiment.

We have seen that dilatation of the pupil is still obtained after section of the sympathetic. No vaso-motor fibres are known to run to the iris except by way of the sympathetic, and even if such exist, the experiments of Langley and Anderson[14] tend to show that vascular effects are inefficient to bring about the dilatation observed.

Moreover it is well known that changes in blood-pressure may occur from stimulation of various parts of the cortex, whereas pupil dilatation only occurs from certain localised spots in the absence of the epileptoid state.

It seems justifiable from these considerations to regard the effect as another instance of direct inhibition of the oculo-motor nerves from the cortex.

I do not propose to enter into the question of the relationship of these pupillary foci in the cortex further than to say that Bechterew and Mislawski's nomenclature strikes me as unfortunate.

IX. Summary.

(1) Dilatation of the pupil, like other effects of cortical stimulation, is best obtained with slight anæsthesia. It often occurs without any movement of the eyes or body, but most markedly in those epileptic convulsions which often follow frequent or prolonged excitation. It is never seen with deep anæsthesia.

(2) In the absence of the epileptic condition, it is only obtained from those parts of the brain which are concerned in eye movements—*i.e.*, from the frontal motor area for the eye muscles, and from the occipital 'visual centre.' The differentiation of these areas, both for eye movements and pupillary dilatation, is much more exact in the monkey than in cats and dogs. In the latter animals, dilatation may occur from stimulation over considerable areas of the frontal and occipital regions, but is best and most constantly obtained from the sigmoid convolution around the crucial sulcus and from the mesial surface of the brain in the same region, and from the posterior part of

the 3rd or median convolution (ecto-lateral and posterior supra-sylvian gyri).

(3) When well marked the dilatation of the pupil is accompanied by all the usual effects of stimulating the cervical sympathetic.

(4) The effect is sometimes more marked upon the opposite eye.

(5) The effect is diminished, but by no means abolished, by section of both sympathetic nerves in the neck. The other sympathetic effects are abolished.

(6) The effect is not influenced by section of the V. nerves intra-cranially after previous section of the cervical sympathetics.

(7) The effect is abolished by section of the III. nerves intra-cranially after previous section of the cervical sympathetics.

(8) The effect is not abolished on either side by section of the corpus callosum.

(9) In the absence of the usual dilator tracts, the effect is probably due to an inhibition of the tonic action of the III. nerves.

In conclusion I wish to thank Professor Starling for allowing me to work in his laboratory, and Dr W. A. Osborne for kindly assisting me in the experiment upon the monkey.

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APPENDIX.

The following are abstracts of some of the experiments.

EXP. X. Cat. A.C.E. Both sympathetics prepared. L. frontal lobes exposed and continued back over occipital lobes.

A.M.

11.15 Stimulate mesial surface near crucial sulcus = dilatation of both pupils with retraction of nictitating membranes, esp. marked on R. side. No movements of body. Stimulate post-supra-sylvian convolution = same effect but more marked. Other parts of exposed area stimulated with negative results.

11.40 Stimulate mesial surf. near crucial = usual result with contraction of orbiculares palpebrarum, esp. opp. side.

11.42 Stimulate post-supra-sylvian convolution = usual effect, no body movements. Repeated several times at intervals.

12.0 Cut L. symp. Stimulate oral end = wide dilatation. Stimulate sigmoid gyrus = dilatation of both, R. > L. Stimulate post-supra-sylvian = ditto, but less marked.

* * * * * * *

P.M.

12.45 L. cortex removed. Stimulate R. cut surface of corpus callosum = movements of L. side of body and dilatation of both pupils, R. > L.

12.50 L. III cut, pupil dilates to $\frac{3}{4}$. Stimulate corpus callosum = R. dilates, L. immobile.

1.0 R. symp. cut... Stimulate corpus callosum = very slight dilatation.

1.10 R. pupil < $\frac{1}{4}$: stimulate mesial surface of R. hemisphere = slight dilatation of R. pupil.

EXP. XII. Cat. A.C.E. Sympathetics prepared. L. cortex exposed.

P.M.

12.0 Stimulate sigmoid = marked dilatation, rapid recoil.

12.5 Stimulate post-supra-sylvian = ditto, more marked. Cut L. symp.

12.10 Pupils R. = $\frac{1}{4}$, L. < $\frac{1}{4}$.

12.13 Stimulate sigmoid, R. > $\frac{3}{4}$, L. > $\frac{1}{2}$, longer latent period, eyes down and to R.

12.17 Corpus callosum divided. R. = $\frac{1}{4}$, L. < $\frac{1}{4}$.

12.20 Stimulate sigmoid = R. $\frac{1}{2}$, L. nearly $\frac{1}{2}$.

12.22 Stimulate post-supra-sylvian = ditto, eyes straight. Repeated several times.

12.30 Cut R. symp.

12.33 Both = $\frac{1}{4}$: stimulate sigmoid, both = $\frac{1}{2}$: repeat = ditto. Stimulate 2nd ext. (post. pl.) = ditto.

12.40 Stimulate central end of cut L. sciatic n. = marked dilatation of both ($\frac{3}{4}$).

12.50 Cut L. III. R. > $\frac{1}{4}$, L. > $\frac{1}{2}$. Stimulate sigmoid = R. = $\frac{1}{2}$, L. nil.
[The corpus callosum was completely divided except at splenium.]

EXP. XIV. See *Brit. Med. Jl.*, Sep. 15, 1900.

EXP. XVI. Cat. Ether. Both sympathetics prepared. L. cortex exposed.

A.M.

11.45 Lateral nystagmus, ·56 per minute. Stimulate sigmoid = nil—deep anæsthesia. Pupils equal, $\frac{1}{4}$.

P.M.

12.0 Stimulate sigmoid = slight dilatation. Stimulate post-supra-sylvian = dilatation to > $\frac{1}{2}$, R. ear pricked up.

12.4 Stimulate sigmoid = eyes to opp. side, both dilate; nystagmus increased in range and frequency.

* * * * * * *

12.10 R. symp. pulled out as high as possible.

12.12 Pupils R. = nearly $\frac{1}{2}$, L. = $\frac{1}{4}$: stimulate sigmoid, R. = nearly $\frac{3}{4}$, L. = fully $\frac{3}{4}$: stimulate post-supra-sylvian = ditto.

Exp. XIX. Cat. Ether. R. supr. cervical gang. excised, R. X intact, L. X and symp. divided. L. frontal cortex exposed.

P.M.

4.30 R. = $\frac{1}{4}$, L. slightly larger: stimulate L. sigmoid = dilatation of both.

4.40 Deeply anæsthetised, both = $\frac{3}{4}$: stimulate sigmoid = nil.

4.44 Pupils, R. = $\frac{1}{2}$, L. slightly larger. Stimulate sigmoid, R. = $\frac{3}{4}$, L. very slight dilatation, R. orbicularis palpebrarum contracts.

4.48 Repeat = ditto.

4.50 No reaction to strong electric light in either ($\frac{1}{3}$).

4.52 Pupils $\frac{1}{3}$: stimulate sigmoid = $\frac{1}{2}$, both.

Exp. XX. Large cat. Ether. This cat gave very good localisation results. It is mentioned because the cerebellum was exposed and the L. lateral lobe stimulated. The eyes moved to the same side, and the pupils dilated from $\frac{1}{4}$ to $\frac{1}{2}$. This was repeated in another cat with the same result.

Exp. XXIX. Cat. A.C.E., then ether. R. vago-symp. cut, L. symp. cut. Post-pt. of L. cortex and cerebellum exposed. L. V cut.

P.M.

2.0 Stimulate post-supra-sylvian = dilatation from $\frac{1}{4}$ to $\frac{1}{2}$.

2.3 Pupils $\frac{1}{4}$, equal. Coil at 7; stimulate post-supra-sylvian = eyes to R. and up, dilatation to $\frac{3}{4}$, no body movements.

2.4 Coil 13. Repeat = slight dilatation, no movements.

2.5 Coil 11. Repeat = dilatation from $\frac{1}{4}$ to $\frac{1}{2}$, eyes to R.

2.7 Repeat = ditto. Stimulate ant. part of post-supra-sylvian = nil.

2.8 Repeat = ditto.

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2.13 Pupils equal, $\frac{1}{2}$: stimulate median ecto-sylvian = nil. Coil 10. Stimulate median ecto-sylvian = eyes up, slight dilatation. Stimulate post-supra-sylvian = wide dilatation.

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2.25 Stimulate L. conjunctiva = nil: stimulate R. conjunctiva = dilatation of both to $\frac{3}{4}$. 2.27 Repeat = ditto. 2.30 Repeat = ditto. Dilatation very slow but marked.

2.31 Pupils $\frac{3}{4}$—A.C.E. on—pupils gradually contract under influence of chloroform.

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2.40 Stimulate internal capsule = no effect, except from post. part = strong convergence of eyeballs and both pupils contract very markedly.

[The V. nerve was completely divided.]