CONSCIOUSNESS AND THE CEREBRAL CORTEX

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The scientific study of consciousness is difficult. Indeed, the enterprise seems to be almost a contradiction in terms. By most people's standards science cannot begin until the subject to be investigated has a definition, written down and generally agreed. "Consciousness" has no such definition. There have, in fact, been many serious attempts to remedy the situation. The most successful move consisted of a change of name. "Level of arousal" is the phrase usually used by psychologists to refer to those aspects of human experience and animal behaviour which are linked to "consciousness". The change of label is itself important and constructive. "Consciousness", with its antithesis "unconsciousness", implies a bistable system. "Level of arousal" implies that the system is capable of subtle and continuous variation—obviously a much better description of what one actually observes. Unfortunately, the invention of a rather better name has been the only successful step towards adequate definition. Attempts to go further, and to achieve the scientific ideal—a fully agreed definition, specifying measurable changes in a clearly defined variable—have all failed. Definitions abound, but consensus is totally unobtainable, a failure which has been described and documented by Andrew (1974).

"Consciousness" is therefore bereft of scientific respectability. One cannot measure what one cannot define. Still less can one ask how it works. Yet the subject is too important to be left to the logicians. Variations in consciousness, or level of arousal are central to the practical aspects of anaesthesia and psychiatric medicine. In addition, it is a commonplace but important observation that almost every aspect of our sensory experience and our motor performance is altered when we become either more alert, or less so. In fact, experimental psychologists, who are forced to cope with intact subjects, both human and animal, have for many years recognized that the relationship between level of arousal and success in performing any skilled task is, in principle, predictable. Accounts of this relationship can be found in almost any textbook of general psychology. It is, however, much more difficult to discover a description which is intelligible. Most are laden with jargon. In fact Hebb (1972) gives an account which is beautifully lucid.

Experimental neurophysiologists have not been forced to come to terms with intact subjects. On the contrary, their techniques often require that their animals be very far from intact. For example, the standard methods of examining the activity of nerve cells in the central nervous system demand a degree of mechanical stability which is most easily achieved by using a preparation which is not only anaesthetized but also paralysed. Under these conditions it is very easy to decide to study a "system", in isolation.

The first successful recordings from unanaesthetized animals were made between 1950 and 1960. In 1959, for example, Hubel recorded from cells in the visual cortex of the lightly restrained cat. He observed the activity of nerve cells as the animal fell asleep, and was able to report that neuronal activity continued, apparently unabated, in the sleeping state. In 1964 Evarts extended this kind of work to single cells in monkey motor cortex. His animals were clamped in order to maintain mechanical stability; apparently both cats and monkeys will calmly tolerate rigid clamping of the head, provided that they have been properly trained to do so . . . the difficulty then is said to be to keep them awake in so tedious an environment. Evarts made the important observation that although neuronal activity was maintained during sleep, it changed in a specific way.

Only the transition from placid wakefulness to sleep can be successfully observed in a restrained animal. Any other change in the animal's general state (sudden excitement, for example) ruins the recording apparatus. For this reason Burns, Stean...
and Webb (1974) developed a technique for recording the activity of single cells in the cerebral cortices of cats which were neither anaesthetized nor restrained. As soon as the animal is free to behave normally it becomes clear that level of arousal is one of the most important determinants of cortical activity.

The nature of spontaneous cortical activity

A micro-electrode lying close to the soma of a cortical neurone records a series of brief, all-or-nothing electrical signals, known as action potentials (fig. 1). The series is unpredictable, in the sense that knowing when one action potential occurred does not permit one to predict the precise time at which the next will happen. The series is also continuous, in the sense that action potentials seem to be produced throughout the life of a nerve cell—day and night, waking and sleeping; even if the subject is lightly anaesthetized. This is described as "spontaneous" activity. It is spontaneous insofar as it appears to happen without deliberate experimental stimulation. Whether it is genuinely independent of sensory input (in the same way as is the electrical activity of mammalian heart muscle) is dubious.

Commonly used arithmetic descriptions of spontaneous activity

Mean frequency of discharge. If one counts the number of action potentials per unit time it is clear that the mean frequency of discharge for a given neurone is stable when measured over a long period, but is subject to sudden short-term fluctuations. These variations are often quite dramatic—there may be a period of complete silence lasting perhaps a few seconds, or the firing frequency may suddenly increase by anything up to a factor of 10. Each neurone has its own mean frequency, and its own range of variation. Neither seems to be related in any obvious way to the activity of neighbouring cells, nor (in most cases) to what the animal is doing.

Temporal pattern of discharge. A slightly more complicated way of describing spontaneous electrical activity is to look at the temporal pattern displayed in a train of action potentials. If one examines the discharge train shown in figure 1, it is quite clear that the intervals between successive action potentials (otherwise known as "interspike intervals") are not all of the same duration. In other words, the neurone is transmitting a kind of morse code. One standard graphical description of the morse code is known as an "interval distribution", and the procedure for constructing this type of graph is shown in figure 2. An interval distribution graphs the number of interspike intervals of various durations which are present in a given train of action potentials. A comparison between the upper and lower graphs of figure 2 shows that it is possible for the interval distribution to alter without any corresponding change in mean frequency of discharge. Figure 3 shows a real interval distribution. The shape of the curve is typical. There are relatively few very short intervals; the graph rises to a peak at the modal, or most common interspike interval, and then slowly declines. Very long interspike intervals are rare. A simple manoeuvre transforms such a graph into one which is easy to describe mathematically. If an interval distribution is replotted on a logarithmic abscissa, than the resulting graph approximates satisfactorily to a statistician's normal distribution (Burns and Webb, 1976). This process is illustrated in figure 3, right graph. We do not know why this trick works, but it is technically very useful since the shape of the resulting graph can be described in terms of the two defining parameters of a normal distribution, the modal or most common interval and its standard deviation, a measure of scatter about the mode. Because our curve is plotted on a logarithmic abscissa, its standard deviation must be measured in logarithmic units, and should be referred to as a "geometric standard deviation".

Relationship between level of arousal and spontaneous activity

Mean frequency of discharge. Mean discharge fre-
Fig. 2. The method of construction of an interval distribution. A series of hand-drawn “action potentials” is shown in the upper left portion of the diagram. The corresponding interval distribution appears on the upper right. In order to make the distribution, the times between action potentials have been classified according to their duration (the classes are 1–4, 1 being the shortest and 4 the longest). The number of intervals of each class has been counted and plotted (upper right). Interval distributions usually show a “modal”, or most common, interval. In the upper interval distribution the modal interval is class 2. The lower part of the diagram consists of a second set of action potentials, together with the appropriate interval distribution. This illustrates the fact that the modal interval can shift (from class 2 to class 1) without any alteration in discharge frequency.

Fig. 3. The left graph shows a real interval distribution, derived from a train of 200 action potentials recorded from a neurone in the parietal cortex of the cat. The modal, or most common, interval is about 50 ms. The right graph shows the same interval distribution replotted on a logarithmic abscissa. Superimposed is the appropriate best-fit normal distribution (from Webb, 1976a).
frequency per unit time gives, of course, the simplest possible description of neuronal discharge. Unfortunately, the relationship between mean frequency and level of arousal is not correspondingly straightforward. There is a statistical relationship between, for example, the discharge frequency of a cell when an animal is awake and the firing rate of the same neurone when the animal is asleep. However, the relationship can only be seen if one gathers together observations from large numbers of neurones (Burns and Webb, 1982). The nature of this relationship is shown in figure 4. Similarly, the firing frequency while an animal is awake and relaxed is related to the frequency seen if the level of arousal is increased by a sudden fright (fig. 5). Taken together, figures 4 and 5 suggest that the

![Figure 4](http://bja.oxfordjournals.org/)

**FIG. 4.** Showing the relationship between the firing frequency of a cortical cell recorded when an animal was awake, and the frequency of the same cell when the animal was asleep. The straight line was fitted to points derived from all 109 neurones, but, for the sake of clarity, the points marked on the diagram are mean values for groups of cells. The graph summarizes the results reported by many workers (see Burns and Webb (1982) for a list of sources).

![Figure 5](http://bja.oxfordjournals.org/)

**FIG. 5.** Showing the relationship between the firing frequency of a cortical cell recorded when the animal was awake and relaxed, and the frequency of the same neurone when the animal was alarmed. Each point on the graph represents the activity of one cell (from Burns and Webb, 1982).
number of action potentials produced is, indeed, affected by level of arousal, but that the changes in frequency are usually too small and unreliable to be of much use as a measure of arousal.

Temporal pattern of discharge. The interval distribution, although initially more complicated to calculate, is linked to level of arousal in a way that is simple and striking. If one arranges for a loudspeaker to click every time an action potential is produced, and then merely watches the animal and listens to the action potentials, it is obvious that the pattern of discharge changes whenever the animal becomes bored, excited, or somnolent. Figure 6 shows what happens to the interval distribution recorded from a neurone in the parietal cortex when an animal, which was peacefully awake, finally falls asleep. The upper graph gives the “raw” interval distributions; the lower shows the best-fit log-normal curves. The changes can best be seen by looking at the log-normal curves. When the animal fell asleep the modal interval became shorter, and the geometric standard deviation became greater. Figure 7 illustrates the results of an experiment dealing with the other end of the scale—the transition from relaxed wakefulness to a very high level of arousal. In this case, the changes are of the opposite kind, that is a lengthening of the modal interval and a decrease in the size of the geometric standard deviation. The experiment of figure 7 was not performed on the same animal as the experiment of figure 6. When the whole sequence of events can be carried out while recording from the same neurone, a family of log-normal curves emerges (fig. 8). In other words, there is a systematic relationship be-

![Fig. 6. Showing the effects of falling asleep upon the spontaneous activity of a neurone in cat’s parietal cortex. The upper part of the figure shows two interval distributions recorded from the same cell, one while the cat was awake (continuous line), the other after he had fallen asleep (interrupted line). The appropriate best-fit log-normal curves appear in the lower part of the figure. It can be seen that the mode became shorter when the animal fell asleep, and the geometric standard deviation increased (from Webb, 1976a).](image)

![Fig. 7. The effect of alarm on the interval distribution of a neurone in the cat’s visual cortex. The upper part shows two interval distributions describing the activity of the cell when the cat was relaxed (broken line), and when he was alarmed (continuous line). The lower part shows the appropriate log-normal curves. During alarm the mode became longer and the geometric standard deviation smaller (from Webb, 1976b).](image)
FIG. 8. The normal curves which best describe the activity of one cell (a neurone in the cat's parietal cortex) at three different times during the same experiment. The curve on the extreme left represents the cell's activity when the cat was peacefully asleep. The middle curve was derived when the animal was awake and alert. The right-hand curve describes the interval distribution recorded during alarm (from Webb, 1976b).

tween the temporal discharge pattern of individual cortical cells and the level of arousal of the animal as a whole (Webb, 1976a, b).

One other interesting feature of the relationship between level of arousal and discharge pattern is the fact that the discharge patterns recorded during slow-wave sleep and REM sleep are similar. The great contrast between the EEG in slow-wave sleep and the EEG typical of the REM phase might lead one to expect that the activity patterns of cortical neurones would also show a marked contrast. On the contrary, the two states of sleep are related to interval distributions which are more notable for their similarities than their differences. The modal interval of REM sleep tends to be slightly longer than the modal interval of slow-wave sleep, and the geometric standard deviation may be considerably smaller. Yet neither interval distribution could be mistaken for a "waking distribution". The simple fact that the animal is unconscious seems to be the prime determinant of the temporal pattern of discharge.

The results of studying the two transitions, one from waking to sleep and the other from relaxation to alarm, suggest that the temporal discharge pattern of individual cortical cells is locked to the animal's level of arousal. One might then expect that every subtle shift in mood would be accompanied by the appropriate modulation of spontaneous cortical activity. This continuous relationship is not easy to demonstrate, simply because there is no independent measure of level of arousal. Consequently, following small alterations, rather than examining well-defined end-points, presents almost insuperable methodological problems. One possible experiment might involve first alarming the animal, and then leaving him until he calms down and finally falls asleep. This simple sequence of events should produce a slow steady decrease in level of arousal, which should therefore be reflected in an equally steady progression of modal intervals and geometric standard deviations towards sleep values. The sequence of events, as described, is usually very different from the sequence achieved in practice. A real cat does not simply calm down, then begin to purr, next lie down and finally fall asleep. Once a real animal is no longer frightened it gets bored and looks for amusement, feels hungry, or simply wants to get out of the cage. In short, the ideal behavioural sequence is virtually impossible to produce. Figure 9 shows what happened to a single neurone in parietal cortex during the most satisfactory behavioural sequence which I have observed. There is a fairly smooth progression of the modal interval towards "sleeping.
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FIG. 9. This graph shows successive changes in one parameter of the interval distribution, the modal interval, as an animal gradually relaxes after a fright. The stippled horizontal band represents the range of modal intervals displayed by the cell in the period of relaxation before the cat was alarmed. At time zero the animal jumped to his feet in response to a hiss of compressed air. Simultaneously, the modal interval became very long. He then began to relax, and the modal interval steadily shortened until the sixth minute. At this point (marked by the arrow) he was accidentally frightened by the rustling of a plastic apron and the modal interval lengthened once more. By the nineteenth minute, the cat was lying down and his eyes were shut. The experiment ended when someone walked down the corridor in squeaky shoes, whistling.

data values”—a progression interrupted at one point when the cat was accidentally startled for a second time.

The general proposition that the pattern of cortical activity is directly related to level of arousal should also be supported by evidence that an “unconscious” interval distribution can be seen, however unconsciousness is produced. In other words, light anaesthesia should have the same neuronal effects as does sleep. There has been little systematic work on the subject, Noda and Adey’s (1973) paper being the only thorough investigation of the matter. It is quite clear from this work that a record made under light thiopentone anaesthesia is almost indistinguishable from a record made from a sleeping cat. Our own occasional observations of the effects of light halothane anaesthesia are very similar.

In the same line of argument REM and SWS sleep should both produce an “unconscious” interval distribution. This they do. There are minor differences between the interval distributions produced by the two states, but neither could be mistaken for a distribution taken from a waking animal.

At the other end of the scale it should be possible to demonstrate that the “highly aroused” interval distribution is not peculiar to high arousal produced by alarm. Many of the events which result in increased levels of arousal could be described as tinged with alarm; for instance, any novel experience. But there are some situations in which excitement has little to do with fear; straightforward hunger, for example. Again, the practical experimental difficulties are formidable, and the best that can be done is to provide the results of a couple of isolated experiments in which all the behavioural requirements were fulfilled. The first experiment (fig. 10, upper graph) shows that as a hungry cat is being fed, the modal interval becomes progressively shorter. This experiment is far more difficult to perform than its description suggests. One would only expect to find a predictable sequence of interval distributions if the animal simply starts to eat, and then continues to eat without distraction until he is replete. Unfortunately, an unimpeded hungry cat eats so quickly that it is only occasionally possible to record enough action potentials.

The lower graph of figure 10 concerns the effects of another form of high arousal on another nerve cell in another cat. This time the cat was playing a repetitive game with which he rapidly became bored. Figure 10 shows that the process which began with wild feline excitement, and ended with a bored refusal to play, was accompanied by a steady shortening of the modal interval.

Which cortical neurones display this relationship between level of arousal and temporal pattern of discharge?

The experiments described above all involved records made from randomly selected nerve cells in the cerebral cortex of the cat. Cells in visual, parietal and auditory cortex all show similar modulation, so
it seems that cortical cells transmit information about the animal's level of arousal in addition to any more specific information concerned with, for example, sensory processing. Although other workers have used different numerical methods to describe their findings, it is clear that Noda and Adey (1970) observed similar changes in cortical activity when their animals (also cats) fell asleep, as did Evarts (1964), who recorded from monkey motor cortex. More recently, A. J. S. Summerlee and A. C. Paisley (personal communication) have observed both the wake–sleep transition, and the relaxation–alarm transition in both rat and rabbit. They report the same systematic changes in interval distribution. Similar changes have also been observed in the forebrain of the quail (Foster, Paisley and Summerlee, 1982). It seems therefore that the activity of many cortical neurones in many species of animal is constantly modulated to suit the mood of the moment, and that the other, more specific functions of individual nerve cells must be superimposed on a "morse code" which signals the animal's general state.

However, every study of single cell activity runs the risk of sampling bias—the tendency for electrodes (and experimenters) to record predominantly from neurones of one particular anatomical type (Towe and Harding, 1970). Such a tendency may yield a picture of uniformity where none, in fact, exists. There is some evidence that this has happened in the kind of work described above. Steriade (1978) has attempted to distinguish, on physiological grounds, between two types of cortical neurone, Golgi type 1, and Golgi type 2. Type 1 cells are neurones the axons of which leave the cortex and transmit information to other parts of the brain; they are often relatively large. Type 2 cells, which are often small, receive and transmit information within the cortex itself. Steriade made a serious effort to record from both types of neurone, and his results suggest that the activity of the type 2 cells is not governed by arousal in the same straightforward way as is the activity of the type 1 cells.

In summary, there is good evidence that the activity of many cortical neurones, in several species, changes from moment to moment as the animal's degree of alertness fluctuates. It seems inescapable that the other functions of the neurones concerned must be superimposed on this background activity and that, consequently, specific sensory information cannot be divorced from information about the animal's general state at the moment of perception. It is uncertain whether all cortical neurones register the animal's general state in this way. One author has in fact suggested that there are two quite distinct classes of neurone, and that only one of them displays this kind of arousal-locked modulation.

**How does the modulation of cortical nerve cells come about?**

Classically, the activity of any given neurone is altered by the activity of other neurones, operating via a network of nerve processes and synapses. There is, however, an alternative type of mechanism, which might seem particularly appropriate when widespread, simultaneous changes occur in many nerve cells, as of course must happen when an animal's level of arousal changes. This second possibility is that the changes are effected in a humoral manner, by chemicals which travel in the blood-
stream or cerebrospinal fluid, and in this way have direct access to each nerve cell.

It is (just!) possible to sort out these two alternative explanations by recording the spontaneous activity of nerve cells within "islands" of chronically isolated cerebral cortex. The large blood vessels supplying the cerebral cortex lie on the surface of the cortex in the subarachnoid space, and the cortical substance ultimately receives its nourishment from capillaries which dip down perpendicular to the surface of the brain. Consequently, it is theoretically possible to sever the neuronal connections to and from an area of cortex while maintaining an adequate blood supply to the neurologically isolated slab. After isolation, recording electrodes are positioned in the isolated slab; bone, muscles and skin are repaired, and an otherwise intact animal becomes host to an area of cerebral cortex which is disconnected from the rest of the brain, but is in physiologically good condition.

The theory is a good deal better than the practice, but even the practice works occasionally, in which case the isolated cells begin to show spontaneous activity a few days after operation. At first the activity is grossly abnormal, but its statistical properties soon become indistinguishable from those of neurones in intact cortex. It is worth noting that the animal itself never shows any ill effects after this operation; it seems to be a perfectly normal cat. When the "host animal" goes to sleep, the isolated neurones fail to follow suit (fig. 11). The interval distributions of such cells are very stable. Moreover, they usually resemble distributions recorded from intact cortex when an animal is alarmed. These experiments suggest two things. First, that the modulation of cortical activity to match level of arousal is dependent on a neural subcortical network, rather than a direct humoral mechanism. Second, since isolated cells tend to produce "highly aroused" patterns of discharge, the neural network must, in normal circumstances, become more active as the level of arousal decreases (Burns, Stean and Webb, 1979). A more precise definition of the relevant neural network, in either anatomical or chemical terms, awaits further experimentation.

**Relationship between interval distribution and EEG**

It has been known for many decades that the EEG changes dramatically when a human or animal falls asleep. As a consequence, the idea that the EEG is an efficient indicator of consciousness has become embedded in many scientific minds as a tenet which is unquestioned, and unquestionable. This is a pity. Jouvet pointed out (1967) that "in no way does the state of the corticogram allow us to presume that an animal is asleep or awake". Neither is the EEG a reliable guide to the state of the supposedly anaesthetized human subject (Marshall, Longley and Stanton, 1965).

In fact, the EEG does not seem to be directly related to level of arousal. A more reasonable hypothesis is that it is governed by some other factor which itself often, but not invariably, changes when level of arousal alters. It has been argued (Adrian and Matthews, 1934; Burns and Webb, 1979) that this factor might be described as the "amount of work" done at a given moment by the cerebral cortex (the quantity of sensory information which is being processed) and that a synchronized EEG is seen whenever this decreases below some threshold value. This kind of interpretation is consistent with the fact that "dissociation" of the EEG can be
produced experimentally by various drug treatments, with the consequence that a synchronized EEG appears while the animal is still wide awake (Longo, 1966). This interpretation is also consistent with the desynchronized EEG of REM, or dreaming, sleep. During dreaming, the cortex is processing sensory information of some kind, despite the unconsciousness of the subject.

As one might expect from the preceding argument, there is not much relationship between the interval distributions displayed by individual cortical neurones and the EEG. It is true that, when an animal is quietly asleep, there will be a “sleeping interval distribution” plus a synchronized EEG, but, during REM sleep, the interval distribution remains appropriate to the unconscious state, while the EEG does not. At the other end of the scale, the interval distribution is sensitive to fluctuations in the state of the waking animal (the transition from alarm to quiet alertness, for example) which have no counterpart in the EEG.

Is the cortex the only part of the brain conveying moment-to-moment information concerning level of arousal?

This question is largely unanswered. Work on the effects of increased arousal is very sparse. On the other hand, there is a vast literature concerning the effects of sleep on neuronal activity in various areas of the brain. Much of it is irrelevant to this particular question. Moreover, it is often difficult to draw any conclusions from the literature because of the experimental procedures which have been used. Some workers, for example, paralyse their conscious animals, thus producing a situation which is so unphysiological that any interpretation of results must, at best, be tentative. Even if the animal is theoretically able to move it is often so severely restrained that the EEG is the only criterion by which its condition can be judged. In addition, there is a tendency to study trains of action potentials which are so long that it seems unlikely that the animal remained in a constant state throughout (Burns and Webb, 1976).

Given such problems of experimental technique and interpretation, the statements which follow must be viewed with caution. These statements are no more than an attempt to summarize the literature accurately. Their relationship to “the biological truth” is uncertain.

The ventral posterior, and the ventral lateral nuclei of the thalamus have been examined by separate groups of authors, who agree that cellular activity is modulated during sleep in the same way as is the activity of cortical neurones (Baker, 1971; Lamarre, Filion and Cordeau, 1971). These nuclei are relays for the sensory and motor systems, and are related to the cerebral cortex. One other part of the thalamus has been examined by two research groups. This is the reticular nucleus, which is less intimately related to the cerebral cortex. In this case there is disagreement. Lamarre, Filion and Cordeau found that the neurones changed in the “expected” way when the animal went to sleep, while Mukhametov, Rizzolatti and Tradardi (1970) reported that the cells were virtually unaffected by alterations in level or arousal.

There is an even greater discrepancy as regards the hypothalamus. Findlay and Hayward (1969) recorded from rabbit hypothalamus and their results suggest that the activity of hypothalamic neurones during sleep is quite different from that of cells in the cerebral cortex. However, Summerlee and Paisley (1982) observed the entire range of behavioural states (alarm, relaxation and sleep) in both rats and rabbits, and found that hypothalamic neurones in both species were modulated in the “cortical” way.

At the other end of the scale, there is agreement between independent groups of authors that neither cells in the raphe nuclei (McGinty and Harper, 1976; Sheu, Nelson and Bloom, 1974) nor in the midbrain reticular formation (Manohar, Noda and Adey, 1972; Steriade, Oakson and Ropert, 1982) are influenced by arousal in the “cortical fashion”. Single reports of similar findings have been made with respect to cerebellar cells (McCarley and Hobson, 1972) and neurones in the hippocampus (Noda, Manohar and Adey, 1969).

CONCLUSION

The present state of the art

Good evidence from several sources supports the idea that the spontaneous activity of many neurones in the mammalian cerebral cortex is systematically related to level of arousal. The nerve cells which display this phenomenon appear to be perfectly ordinary neurones in several, functionally discrete parts of the cortex. It therefore seems fair to infer that other, more specific information such as that concerned with seeing, hearing or with motor control is superimposed on spontaneous activity appropriate to “the mood of the moment”. In electrophysiological terms “pure” perception, or “pure” motor output does not exist—the necessary
neural signals are all labelled with the animal's general state at the moment of perception or response. Whether all cortical cells behave in this way is uncertain; it seems probable that some do not, and likely that the distinction between the two neuronal classes will ultimately prove to have important functional implications. As yet, little is known of the mechanisms by which spontaneous activity is modulated from minute to minute. Certain characteristics of the mechanism have been suggested, but that, at the moment, is all.

Finally, there remains the question of the relevance of these observations to the human. There is, of course, no direct evidence that human neurons function in this way. On the other hand, nerve cells in a wide range of species have been reported to do so; it would be surprising if the human were quite different. From the viewpoint of those in need of a practical measure of consciousness, the situation is tantalizing. There seems to be a very good and comparatively simple relationship between the firing pattern of many neurons and state of consciousness, but it is completely inaccessible in human subjects, and is likely to remain so unless somebody finds a direct correlation with some aspect of the EEG.

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REFERENCES


