Relations of Brain Activity and Movement in Animal Hypnosis

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Abstract

1. Seventeen young, adult rabbits had recording electrodes implanted under anesthesia into various parts of the brain. After recovery from surgery, the electrical activity (electroencephalogram, EEG) from these electrodes was recorded before and after 76 test sessions in which the experimenter produced hypnosis by turning the rabbit on its back and holding all limbs and head still for a few seconds.

2. Hypnosis appeared readily, because rabbits are especially susceptible to the manipulation. The behavior of hypnotized rabbits was one of immobility for a few minutes, after which the rabbit terminated the state on its own by righting itself. Immediately after inducing hypnosis, a rabbit's limbs extended and most muscles became tense. But after a couple of minutes, sometimes a more relaxed state followed in which muscle tone decreased and heart and respiratory rates slowed.

3. The brain activity was the same during the first few minutes after hypnosis as it was before hypnosis. The activity was typical of awake rabbits. That is, EEG activity from the part of the brain controlling movements ("motor cortex") was small but very high frequency (that it, is showed many short-duration waves). Activity from the areas deep within the brain were large and rhythmic, averaging about 4/7 waves per second. This so-called "theta rhythm" is prominent in rabbits that are awake and alert.

4. For those test sessions that did not terminate quickly, the EEG signals eventually turned into looking like those that occur during sleep. That is, the cortex waves became larger and slower and the theta rhythm disappeared to become more irregular and slower.

5. On eight occasions in six rabbits, brief episodes of epilepsy-like seizures occurred in the EEG during hypnosis, but there was no corresponding body movement. On other occasions, such seizures were deliberately produced by intravenous injection of seizure-producing drugs (amphetamine, pentylenetetrazol, or diclonine). Hypnosis could abolish the seizure body movements, but EEG signs of seizures would persist.

6. The "arousal" EEG, and especially the electrical seizures, represented a conspicuous example of EEG-behavioral dissociation. That is, the usual correlations between behavioral state and brain state did not occur.

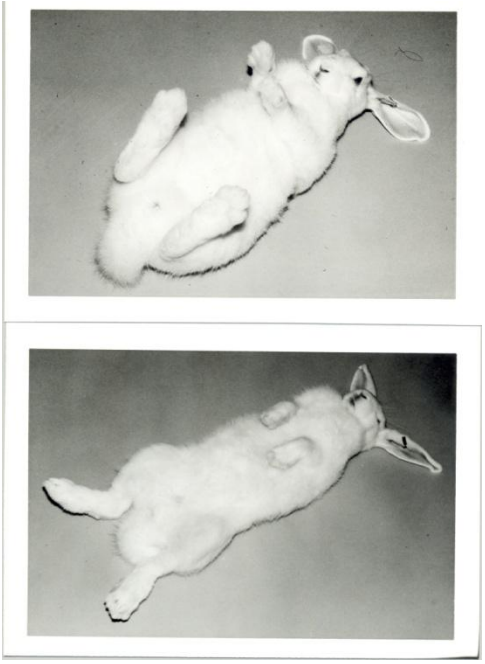
7. The author concluded that this dissociation state indicates that brain activity and behavior do not always correspond. Movement can be disconnected from what is happening elsewhere in the brain. Perhaps the hypnosis manipulations trigger activity in certain brain areas that block movement without affecting level of arousal and awareness.

Introduction

Most people have heard about "hypnotized" animals in which the animal is put into an apparent trance-like, immobile state. This state occurs rather easily in some species, such as the opossum (recall the saying, "playing possum"), birds, guinea pigs, and rabbits. The issue for the author was whether hypnotized animals are really as asleep as they seem to be."Brain waves" ("electroencephalogram," EEG for short) are recordable from scalp electrodes by high-powered

amplifiers. What are actually recorded are the voltages from small electrical currents coming from the brain. Voltages are very small, usually less than 100 microvolts.

Many prior studies had shown a clear association with state of wakefulness and certain patterns in the EEG. So, the author supposed that if hypnotized animals were really asleep, their EEG would look like it would during sleep.



Top: rabbit immediately after hypnosis occurred. Bottom: rabbit after several minutes later. Is the rabbit asleep or awake?

Methods

Four days prior to hypnosis testing, seventeen young adult, anesthetized rabbits had electrodes implanted into various parts of brain. The electrodes were small wires insulated with varnish except at the tips so that the voltages detected were coming mainly from the nerve cells nearest the exposed tips. Electrodes were implanted with a micrometer-driven instrument ("stereotaxic" apparatus) that allowed precise three-dimensional placement. Electrodes were implanted into the hippocampus, thalamus, and hypothalamus. Another electrode was a stainless-steel screw in the skull overlying the motor cortex. Another screw electrode was inserted in skull over a relatively "silent" area over the nose. Thus, amplifiers recorded the voltage difference at each active electrode and the silent electrode over the nose.[1] Dental cement covered all electrodes and exposed scalp and held everything in place and sealed the area to prevent infection. Electrodes were connected to a connector, also anchored in the cement, which could be used for later connection to a cable from the EEG machine during recording.

There is some electrical activity present at the nose that comes from the underlying olfactory bulb. However, the author in separate tests recorded this activity and found it to be unique. The size is small, compared to the signal that was coming from electrodes in the brain.

Scientists call this "reference recording." Voltage difference between the signal at a brain electrode is "referenced" to the very small activity at the nose electrode. In some rabbits, this standard "reference" electrode arrangement was not used. In these, electrode wires were placed in pairs with exposed tips separated by only 2mm. Thus, the activity detected came only from the immediate vicinity of the tip pair, and there was no chance that the signal was "contaminated" by olfactory bulb activity. In any case, the electrical activity was similar, but smaller.

Other electrodes were implanted to monitor dorsal neck muscles, breathing movement, and the heart. Several rabbits had electrodes placed in leg muscles to monitor limb muscle tone.

After surgery, each rabbit received daily doses of antibiotic and rest for three days. All animals were observed for at least 2 weeks after surgery, with no indication of infection or other adverse influences of the surgery. After the experiments, each animal was sacrificed with an overdose of anesthetic. The brain was bathed with formalin and examined grossly and microscopically to confirm the exact location of implanted electrodes.

[1] EEG amplifiers amplify the ***difference*** between voltage at one electrode and another.

A lightweight cable connected the electrodes to a traditional EEG machine used. Cable was suspended over the animal's head with an elastic band so as to permit relatively free movement. Amplifiers were set to record brain signals between 1 and 75 Hz (roughly equivalent to "waves per second"). The data channels for muscle and respiration were set differently tor optimal recording of those signals because they occur at a different frequency range.

After a few minutes of recording from an alert and behaving rabbit, hypnosis was induced by gently turning the rabbit onto its back, while simultaneously using both hands to prevent any limb movement and to hold the head still. The hypnosis terminated in a few minutes when the rabbit spontaneously righted itself. Inverting the rabbit in a V-shaped trough produced much longer periods of hypnosis. The reason is probably the extra contact and pressure on the skin.

Recording sessions occurred each morning over four-months. Testing occurred for a given rabbit at least four times at two-day intervals. During each test session, recording alternated from before and during hypnosis.

In some sessions, seizure-inducing drugs were injected via ear vein to determine what effect if any hypnosis would have on the brain and behavioral effects of the drugs. As a control, random injections of sterile isotonic[2] salt solution was injected.

Results

Hypnosis was easy to induce in all rabbits. Immediately after induction, limbs that had been extended to resist the manipulation relaxed. Muscle recordings indicated that muscle tone decreased. Heart and respiratory rates decreased slightly.

The EEG consisted of an "arousal" pattern in which the activity over the motor cortex was small in size and of high frequency (many waves per second)(Fig. 1). In the subcortical areas with implanted wires, the activity was large and rhythmic (4-7 waves per second). This is typical "theta" activity that is well-known in rabbits to indicate brain activation and

This arousal activity was similar to that known to occur in "dream sleep." A major difference, however is that in hypnosis the body showed no signs of the twitches or rapid eye movements that occur during dreaming. Also, there was some tone in neck muscles, which in dream sleep totally disappears. During hypnosis in rabbits, the eyes remained open and fixed.

In those trials where hypnosis lasted longer than usual, brain and body activity were more typically associated. That is, brain activity was of the sleep type (cortex activity became larger and slower; subcortical activity lost the theta rhythm and became more irregular) and muscle tone, and heart and respiratory rates decreased further (Fig. 1, right panel). Upon righting itself to terminate hypnosis, the activity patterns always returned to the awake type.

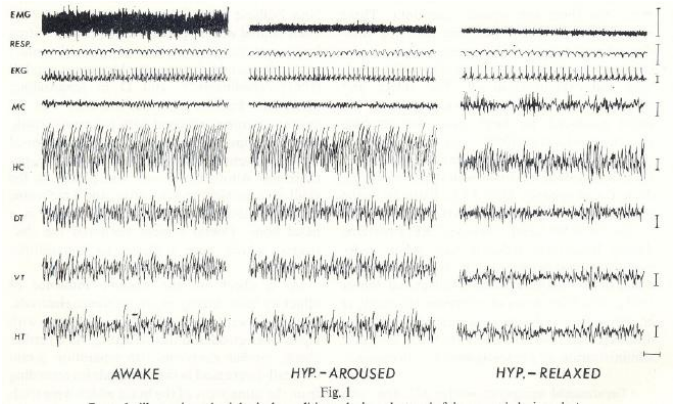


Fig. 1. Note that brain activity is about the same during the awake and hypnotized state (left and middle panel). In long-duration hypnosis states, the activity could change as seen on the right, indicating that the rabbit might have fallen asleep. Top trace in all three panels is muscle activity, which decreases in hypnosis. Second and third traces reflect breathing movement and heart activity. Fourth trace is activity from the motor cortex. Other traces are from electrodes implanted in the brain. Calibration marks on the right and at bottom are 100 μV and 1 second. — note that these are essentially plots of voltage versus time)

[2] Concentration that is osmotically neutral – that is, does not alter the osmotic balance between cells and extracellular fluids.

On eight occasions, EEG signs of seizures occurred during hypnosis, representing an even more dramatic indication that brain activity and body activity need not correlate. This "dissociation" could be repeated at will by injecting certain seizure-producing drugs (Fig. 2).

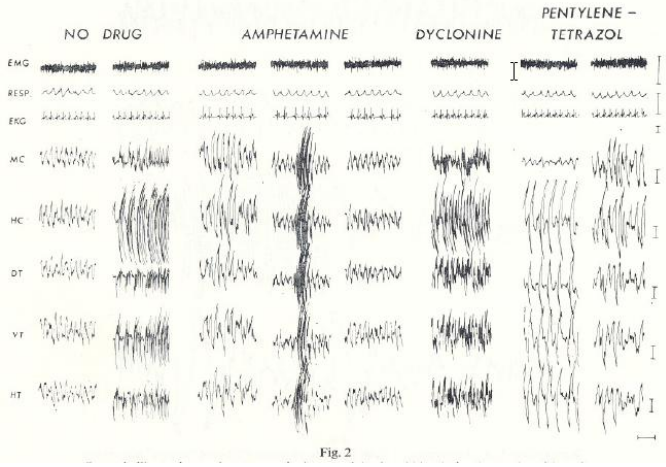


Fig. 2. Different types of brain seizures seen during hypnosis, without drug (left panel) and with various seizure-inducing drugs. Note the absence of corresponding muscle seizures (top trace). This is important because it shows that the seizure activity is not artifact that could have been generated by movement of body or cables during recording. Neither animal nor cable moved during hypnosis, without or without seizure activity.

Control recordings using the paired wire recording revealed that these seizures were uniquely different and not artifact. Thus, the signal must have originated in the recorded brain areas (data not shown here). Such recording from olfactory bulb revealed low voltage, fast activity (20-50/sec) that was not affected by hypnosis nor the seizure-inducing drugs. Other control tests included inverting the rabbit without achieving hypnosis. Such rabbits struggled and muscle activity was greater than in the usual undisturbed awake state. The EEG was unchanged from the awake type.

Discussion

These results confirmed that EEG and behavior can be dissociated. An awake-type EEG can occur when the animal seems to be asleep. This can even include brain seizures in the absence of movement. The author cited other reports (including his own) showing similar dissociations during hypnosis.

The ability of hypnosis to stop seizures of movement but not in the brain itself had not been previously discovered. The seizures were similar to those reported by others with these drugs in non-hypnotized animals. Control tests showed these seizures were not electrical artifact.

The author cited the similarity of these brain seizures during immobility with those he had seen in some anesthetized epileptic dogs.

The author also cited a recent paper in which a variety of drugs could produce a dissociation in the response of the brainstem's "arousal system" to sensory stimulation. The EEG response could be fast or slow and the response to single shocks could be abolition, increase, decrease, or no change.

The author cited other research showing that dissociations could occur in other conditions. Large doses of atropine cause sleep-like brain activity, yet the injected animal or human remains awake. A certain anti-depressant drug can do the same thing.

The opposite kind of dissociation can also occur in which the brain activity is of the awake type, yet the animal or human seems to be sleeping. This occurs during dreaming, injection of high doses of the tranquilizer, reserpine, or simultaneous injection of the stimulant physostigmine and a tranquilizer, and in certain comatose neurological conditions.

As speculation for the cause of the hypnosis dissociation, the author proposed that hypnosis produces a "release phenomenon." The idea is that during hypnosis most brain activity is free to do what it will, while neural pathways that normally produce movement are inhibited. There are neurons and clusters of neurons that have inhibitory effects. The author in other work had identified a couple of areas in brain (pons, midline thalamus) where electrical stimulation actually made hypnosis more profound. Such stimulation presumably activated neurons that inhibit movement.

He concluded that this study shows the limits of our understanding of how sensory input and motor output interact.

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