# THE CYBERNETIC BRAIN

## SKETCHES OF ANOTHER FUTURE

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# 3

# GREY WALTER

## FROM ELECTROSHOCK TO THE PSYCHEDELIC SIXTIES

THE BRUTE POINT IS THAT A WORKING GOLEM IS . . . PREFERABLE TO TOTAL IGNORANCE. . . . IT IS CLEAR BY NOW THAT THE IMMEDIATE FUTURE OF STUDY IN MODELLING THE BRAIN LIES WITH THE SYNTHESIS OF GADGETS MORE THAN WITH THE ANALYSIS OF DATA.

**JEROME LETTVIN**, *EMBODIMENTS OF MIND* (1988, VI, VII)

In an obituary for his long-standing friend and colleague, H. W. Shipton described Grey Walter as, "in every sense of the phrase a free thinker [with] contempt for those who followed well paved paths. He was flamboyant, persuasive, iconoclastic and a great admirer of beauty in art, literature, science, and not least, woman" (1977, iii). The historian of science Rhodri Hayward remarks on Walter's "swashbuckling image" as an "emotional adventurer," and on his popular and academic reputation, which ranged from "robotics pioneer, home guard explosives expert, wife swapper, t.v.-pundit, experimental drugs user and skin diver to anarcho-syndicalist champion of leucotomy and electro-convulsive therapy" (2001a, 616). I am interested in Walter the cybernetician, so the swashbuckling will get short shrift, alas.[1]

After an outline of Walter's life and career, I turn to robot-tortoises, exploring their contribution to a science of the performative brain while also showing the ways in which they went beyond that. I discuss the tortoises as ontological

**Figure 3.1.** Grey Walter. Reproduced from *The Burden: Fifty Years of Clinical and Experimental Neuroscience at the Burden Neurological Institute*, by R. Cooper and J. Bird (Bristol: White Tree Books, 1989), 50. (By permission of White Tree Books, Bristol.)

theater and then explore the social basis of Walter's cybernetics and its modes of transmission. Here we can look toward the present and contemporary work in biologically inspired robotics. A discussion of CORA, a learning module that Walter added to the tortoises, moves the chapter in two directions. One adds epistemology to the ontological picture; the other points to the brutal psychiatric milieu that was a surface of emergence for Walter's cybernetics. The chapter concludes with Walter's interest in strange performances and altered states, and the technologies of the self that elicit them, including flicker and biofeedback. Here we can begin our exploration of crossovers and resonances between cybernetics and the sixties, with reference to William Burroughs, the Beats, and "brainwave music." I also discuss the hylozoist quality of the latter, a theme that reappears in different guises throughout the book.

The ontological hybridity of first-generation cybernetics will be apparent. While we can read Walter's work as thematizing a performative vision of ourselves and the world, the impulse to open up the Black Box of the brain will also be evident. Cybernetics was born in the matrix of modern science, and we can explore that too.

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William Grey Walter was born in Kansas City, Missouri, in 1910.[2] His parents were journalists, his father English, his mother Italian-American. The family moved to Britain in 1915, and Walter remained there for the rest of his life. At some stage, in a remarkable coincidence with Ashby, Beer, and Pask, Walter stopped using his first name and was generally known as Grey (some people understood him to have a double-barreled surname: Grey-Walter). He was educated at Westminster School in London and then at King's College Cambridge, where he gained an honors degree in physiology in 1931 and stayed on for four years' postgraduate research on nerve physiology and conditioned reflexes, gaining his MA degree for his dissertation, "Conduction in Nerve and Muscle." His ambition was to obtain a college fellowship, but he failed in that and instead took up a position in the Central Pathological Laboratory of the Maudsley mental hospital in London in 1935, at the invitation of Frederick Golla, the laboratory's director, and with the support of a fellowship from the Rockefeller Foundation.[3]

Golla encouraged Walter to get into the very new field of electroencephalography (EEG), the technique of detecting the electrical activity of the brain, brainwaves, using electrodes attached to the scalp. The possibility of detecting these waves had first been shown by the Jena psychiatrist Hans Berger in 1928 (Borck 2001) but the existence of such phenomena was only demonstrated in Britain in 1934 by Cambridge neurophysiologists E. D. Adrian and B. H. C. Matthews. Adrian and Matthews confirmed the existence of what they called the Berger rhythm, which later became known as the alpha rhythm: an oscillation at around ten cycles per second in electrical potentials within the brain, displayed by all the subjects they examined. The most striking feature of these waves was that they appeared in the brain when the subjects' eyes were shut, but vanished when their eyes were opened (fig. 3.2). Beyond that, Adrian and Matthews found that "the Berger rhythm is disappointingly constant" (Adrian and Matthews 1934, 382). But Walter found ways to take EEG research further. He was something of an electrical engineering genius, designing and building EEG apparatus and frequency analyzers and collaborating with the Ediswan company in the production of commercial equipment, and he quickly made some notable clinical achievements, including the first diagnosis and localization

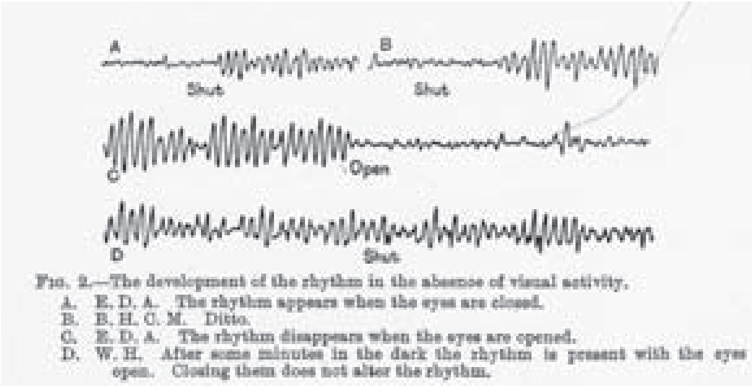


**Figure 3.2.** Alpha rhythms in the brain, showing the effect of opening and closing the eyes. Source: E. D. Adrian and B. H. C. Matthews, "The Berger Rhythm: Potential Changes from the Occipital Lobes in Man," *Brain*, 57 (1934), 355–85. (By permission of Oxford University Press.)

of a cerebral tumor by EEG, the discovery that a significant proportion of epileptics show unusual brainwaves even between fits, and intervention in a famous murder case (Hayward 2001a, 620).[4] Following his pioneering work, EEG was at the center of Walter's career for the rest of his life. In 1949 he was a cofounder and coeditor of the felicitously titled journal *Electroencephalography and Clinical Neurophysiology* (self-described on its title page as "The EEG Journal") and from 1953 to 1957 he was president of the International Federation of EEG Societies.[5]

In 1939 Walter and Golla moved together to the newly established Burden Neurological Institute near Bristol, with Golla as its first director and Walter as director of its Physiology Department (at annual salaries of £1,500 and £800, respectively). The Burden was a small, private institution devoted to "clinical and experimental neuroscience" (Cooper and Bird 1989), and Walter remained there for the rest of his working life, building a reputation as one of the world's leaders in EEG research and later in research using electrodes implanted in the brain (rather than attached to the scalp).[6] Walter's best-recognized and most lasting contribution to brain science was his discovery in the 1960s of contingent negative variation, the "expectancy wave," a shift in the electrical potential of the brain that precedes the performance of intentional actions. He was awarded the degree of ScD by Cambridge in 1947 and an honorary MD degree by the University of Aix-Marseilles in 1949.

Besides his technical work, in 1953 Walter published an influential popular book on the brain, *The Living Brain*, with a second edition in 1961, and in 1956 he published a novel, *Further Outlook*, retitled *The Curve of the Snowflake* in the United States.[7] He was married twice, from 1934 to 1947 to Katherine

Ratcliffe, with whom he had two children, and from 1947 to 1960 to Vivian Dovey, a radiographer and scientific officer at the Burden, with whom he coauthored papers and had a son. From 1960 to 1974 he lived with Lorraine Aldridge in the wife swap mentioned above (R. Cooper 1993; Hayward 2001a, 628). In 1970 Walter's research career came to an end when he suffered a serious head injury as a result of a collision between the scooter he was riding (at the age of sixty, let us recall) and a runaway horse. He was in a coma for a week, suffered serious brain damage, and never fully recovered. He returned to work at the Burden as a consultant from 1971 until his retirement in 1975 and died suddenly of a heart attack in 1976 (Cooper and Bird 1989, 60).

Walter's most distinctive contribution to cybernetics came in 1948, with the construction of the first of his robot tortoises. He was one of the founders of the Ratio Club, the key social venue for the British cyberneticians, which met from 1949 until 1955 (Clark 2002, chap. 3, app. A1). He was an invited guest at the tenth and last of the U.S. Macy cybernetics conferences in 1953 (Heims 1991, 286), and he was a member of the four-man scientific committee of the first meeting of the European counterpart of the Macys, the 1956 Namur conference—the First International Congress on Cybernetics—where he presided over section IV, devoted to "cybernetics and life."

## The Tortoise and the Brain

How might one study the brain? At different stages of his career, Walter pursued three lines of attack. One was a classically reductionist approach, looking at the brain's individual components. Working within a well-established research tradition, in his postgraduate research at Cambridge he explored the electrical properties of individual neurons which together make up the brain. One can indeed make progress this way. It turns out, for example, that neurons have a digital character, firing electrical signals in spikes rather than continuously; they have a certain unresponsive "dead time" after firing; they have a threshold below which they do not respond to incoming spikes; they combine inputs in various ways. But if one is interested in the properties of whole brains, this kind of understanding does not get one very far. A crude estimate would be that the brain contains $10^{10}$ neurons and many, many more interconnections between them, and no one, even today, knows how to sum the properties of that many elements to understand the behavior of the whole. As Walter put it, "One took an anatomical glance at the brain, and turned away in despair" (1953, 50). We could see this as a simple instance of the problem of complexity which will appear in various guises in this chapter and the next: there exist systems for which an atomic understanding fails to translate into a global one. This is the sense in which the brain counted for Stafford Beer as an exemplary "exceedingly complex system."

Walter's second line of attack emerged on his move to London. His EEG work aimed at mapping the properties of the brain. What does the brain *do*? Well, it emits small but complicated electrical signals that are detectable by sensitive electronic apparatus. Such signals, both oscillatory (waves) and singular, were what Walter devoted his life to studying. This proved to be difficult. Other rhythms of electrical activity—the so-called beta, theta, and delta bands of brainwaves at frequencies both above and below the alphas—were discovered, but EEG readouts revealed the brain to be very noisy, and distinguishing correlations between inputs and outputs was problematic. Echoing the findings of Adrian and Matthews in 1934, Walter (1953, 90) observed that "very few of the factors affecting the spontaneous rhythms were under the observation or control of experimenter or subject. Usually only the effects of opening or closing the eyes, of doing mental arithmetic, of overbreathing and of changes in the blood sugar could be investigated. . . . The range and variety of methods were not comparable with the scope and sensitivity of the organ studied, and the information obtained by them was patchy in the extreme." The electric brain, one could say, proved more complex than the variables in terms of which researchers might hope to map it.[8]

We can return to Walter's EEG work at various points as we go along, but I can enter a couple of preliminary comments on it here. As ontological theater, it evidently stages for us a vision of the brain as a performative organ rather than a cognitive one—an organ that acts (here, emitting electrical signals) rather than thinks. Equally evidently, such a conception of the brain destabilizes any clean dualist split between people and things: the performative brain as just one Black Box to be studied among many.[9] At the same time, though, as we will see shortly, Walter's ambition was always to open up the Black Box, in pursuit of its inner go. This is what I mean by referring to the hybrid quality of his cybernetics.

Walter's third line of attack on the brain was the one that I have talked about before: the classically scientific tactic of building models of the brain. The logic here is simple: if a model can emulate some feature of the system modelled, one has learned something, if only tentatively, about the go of the latter, its inner workings. As Roberto Cordeschi (2002) has shown, one can trace the lineage of this approach in experimental psychology back to the early years of the twentieth century, including, for example, the construction of a phototropic electric dog in 1915. The early years of cybernetics were marked by a proliferation of such models, including the maze-learning robots built by Claude Shannon and R. A. Wallace—which Walter liked to call *Machina labyrinthea*—and Ashby's homeostat (*Machina sopora*) (Walter 1953, 122–23), but we need to focus on the tortoise.[10]

The tortoises (or "turtles") were small electromechanical robots, which Walter also referred to as members of a new inorganic species, *Machina speculatrix*. He built the first two, named Elsie and Elmer, at home in his spare time between Easter of 1948 and Christmas of 1949. In 1951, a technician at the Burden, W. J. Warren—known as Bunny, of course—built six more, to a higher engineering standard (Holland 1996, 2003). The tortoises had two back wheels and one front (fig. 3.3). A battery-powered electric motor drove the front wheel, causing the tortoise to move forward; another motor caused the front forks to rotate on their axis, so the basic state of the tortoise was a kind of cycloidal wandering. If the tortoise hit an obstacle, a contact switch on the body would set the machine into a back and forth oscillation which would usually be enough to get it back into the open. Mounted on the front fork was a photocell. When this detected a source of illumination, the rotation of the front fork would be cut off, so the machine would head toward the light. Above a certain intensity of illumination, however, the rotation of the forks would normally be switched back on, so the life of the tortoise was one of perpetual wanderings up to and away from lights (fig. 3.4). When their batteries were low, however, the tortoises would not lose interest in light sources; instead, they would enter their illuminated hutches and recharge themselves.

The tortoises also executed more complex forms of behavior which derived from the fact that each carried a running light that came on when the tortoise was in search mode and went off when it locked onto a light. The running lights were originally intended simply to signal that a given tortoise was working properly, but they bestowed upon the tortoise an interesting sensitivity to its own kind. It turned out, for example, that a tortoise passing a mirror would be attracted to the reflection of its own light, which light would then be extinguished as the tortoise locked onto its image; the light would then reappear as the scanning rotation of the front wheel set back in, attracting the tortoise's attention again, and so on (fig. 3.5). The tortoise would thus execute a kind of mirror dance, "flickering, twittering and jigging," in front of the mirror, "like a clumsy Narcissus." Likewise, two tortoises encountering one another would repetitively lock onto and then lose interest in one another, executing a mating dance (fig. 3.6) in which "the machines cannot escape from one another; but nor can they ever consummate their 'desire' " (Walter 1953, 128, 129).

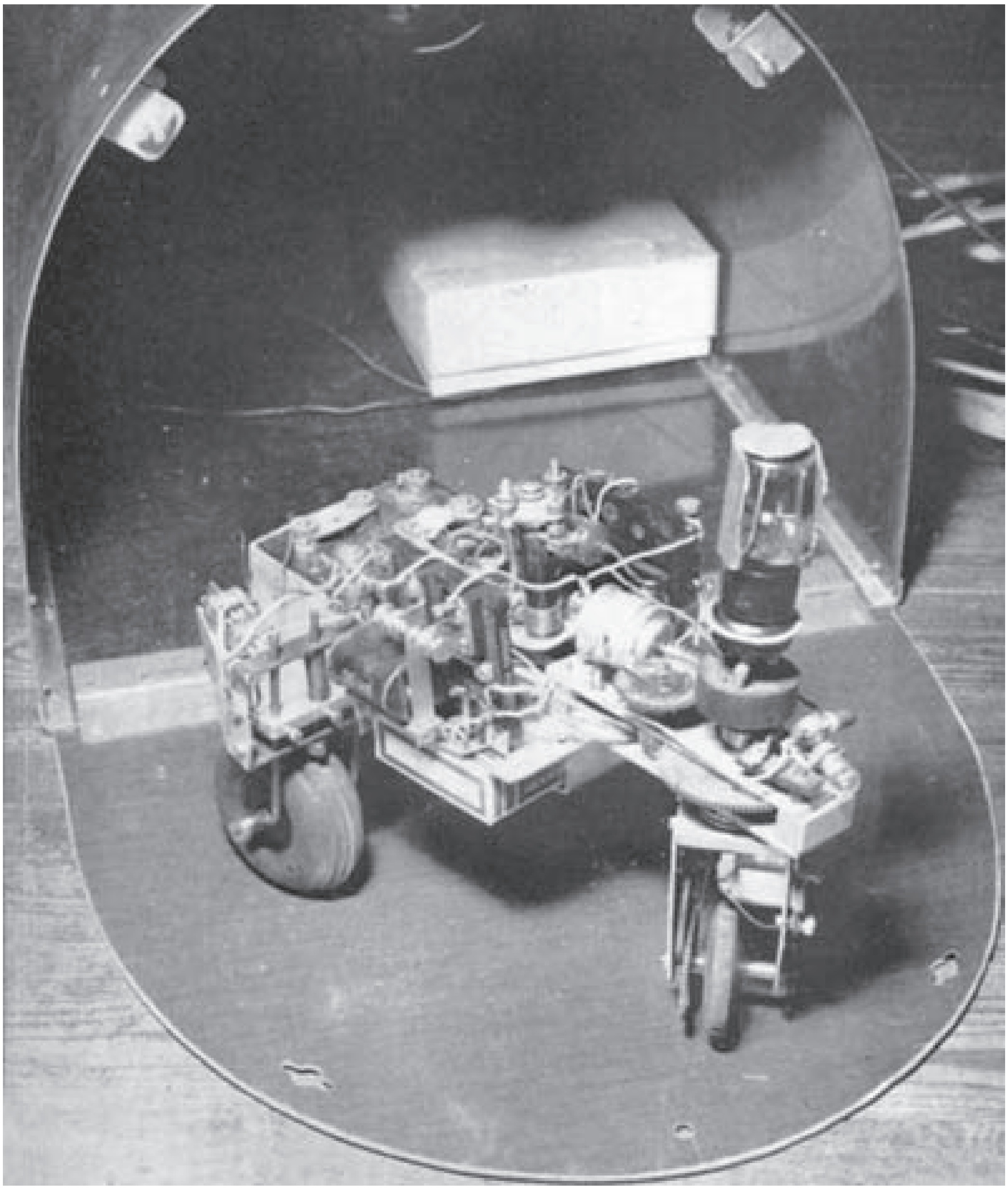

**Figure 3.3.** Anatomy of a tortoise. Source: de Latil 1956, facing p. 50.

So much for the behaviors of the tortoises; now to connect them to the brain. One can analogize a tortoise to a living organism by distinguishing its motor organs (the power supply, motors, and wheels), its senses (the contact switch and the photocell), and its brain (connected to the motor organs and senses by nerves: electrical wiring). The brain itself was a relatively simple piece of circuitry consisting of just two "neurons," as Walter (1950a, 42) put it, each consisting of an electronic valve, a capacitor, and a relay switch (fig. 3.7). In response to different inputs, the relays would switch between different modes of behavior: the basic wandering pattern, locking onto a light, oscillating back and forth after hitting an obstacle, and so on.

What can we say about the tortoise as brain science? First, that it modelled a certain form of adaptive behavior. The tortoise explored its environment and reacted to what it found there, just as all sorts of organisms do—the title of Walter's first publication on the tortoises was "An Imitation of Life" (1950a). The suggestion was thus that the organic brain might contain similar structures to the tortoise's—not valves and relays, of course, but something functionally equivalent. Perhaps, therefore, it might not be necessary to descend to the level of individual neurons to understand the aggregate properties of the brain. This is the sense in which Jerome Lettvin (once a collaborator of Warren McCulloch) could write in 1988 that "a working golem is . . . preferable to total ignorance" (1988, vi). But the tortoises also had another significance for Walter.

The tortoise's method of finding its targets—the continual swiveling of the photocell through 360 degrees—was novel. Walter referred to this as *scanning*, and scanning was, in fact, a topic of great cybernetic interest at the time. The

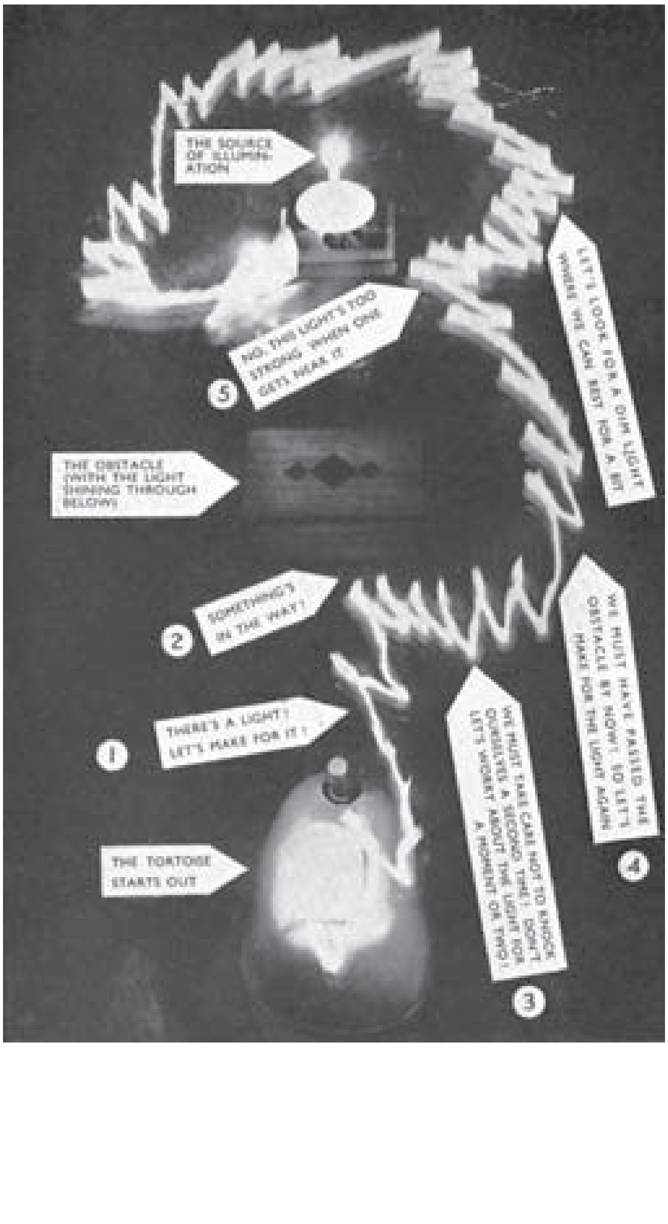


**Figure 3.4.** The tortoise in action. Source: de Latil 1956, facing p. 275.

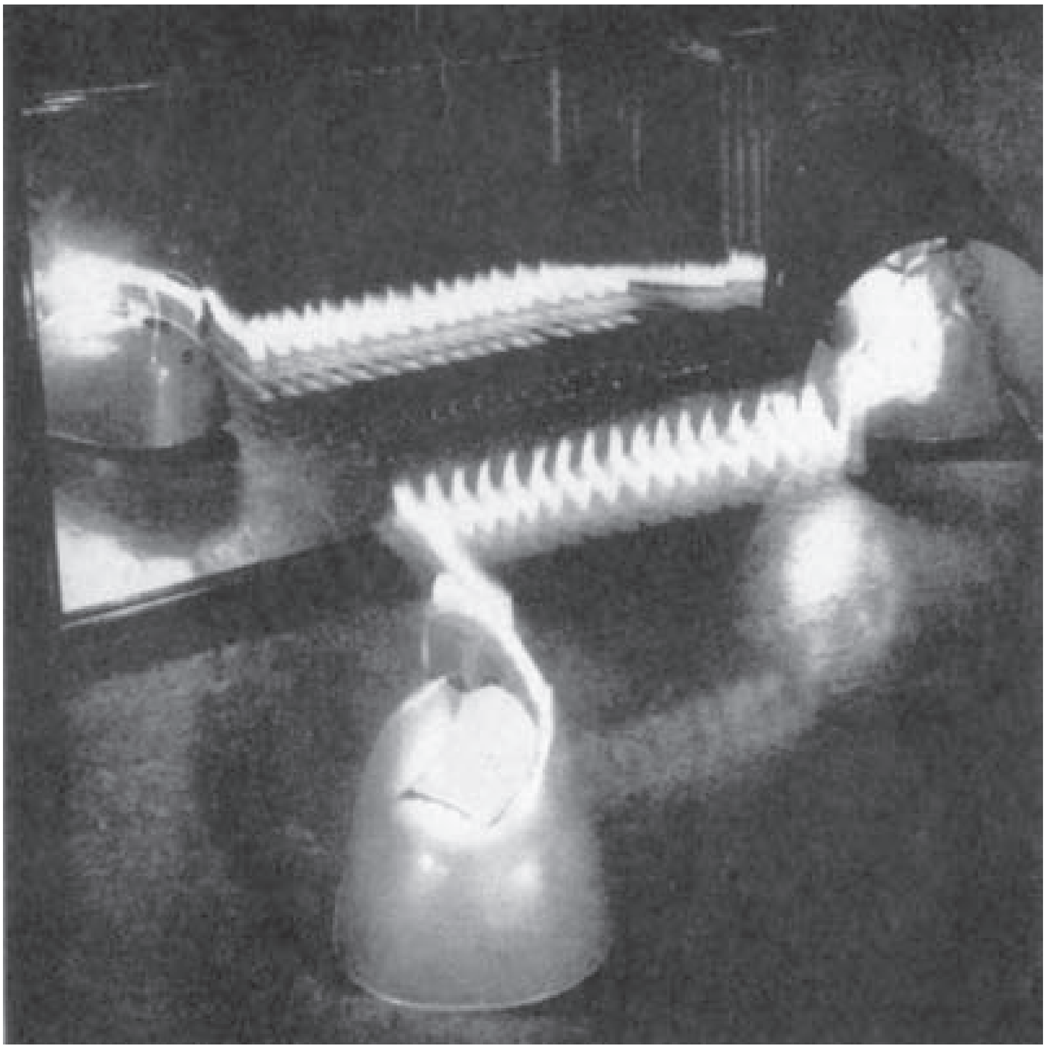

**Figure 3.5.** The mirror dance. Source: Holland 1996.

central question addressed here was how the brain goes from atomistic sensory impressions to a more holistic awareness of the world. In the United States in 1947 Walter Pitts and Warren McCulloch published an influential paper, "How We Know Universals," which aimed to explain pattern recognition—for example, recognizing individual letters of the alphabet independently of their size and orientation—in terms of a scanning mechanism. More relevant to Walter, in his 1943 book *The Nature of Explanation*, Kenneth Craik (1943, 74), the British experimental psychologist, speculated about the existence of some cerebral scanning mechanism, always, it seems, explained by an analogy with TV. "The most familiar example of such a mechanism is in television, where a space-pattern is most economically converted for transmission into a time sequence of impulses by the scanning mechanism of the camera" (Walter 1953, 108). The basic idea was that the brain contains some such scanning mechanism, which continually scans over its sensory inputs for features of interest, objects, or patterns in the world or in configurations internal to itself.[11]

One of the tortoise's most striking features, the rotation of the front forks and the photocell, was thus an implementation of this cybernetic notion of scanning. And beyond that, scanning had a further degree of significance for Walter. Craik visited Walter in the summer of 1944 to use the Burden's automatic frequency analyzers, and from that time onward both of them were drawn to the idea that the brainwaves recorded in Walter's EEGs were somehow integral to the brain's scanning mechanism (Hayward 2001b, 302). The basic alpha rhythm, for example, which stopped when the eyes were opened, could be interpreted as a search for visual information, a search "which relaxes when a pattern is found," just as the tortoise's photocell stopped going

**Figure 3.6.** The mating dance. Source: Holland 1996.

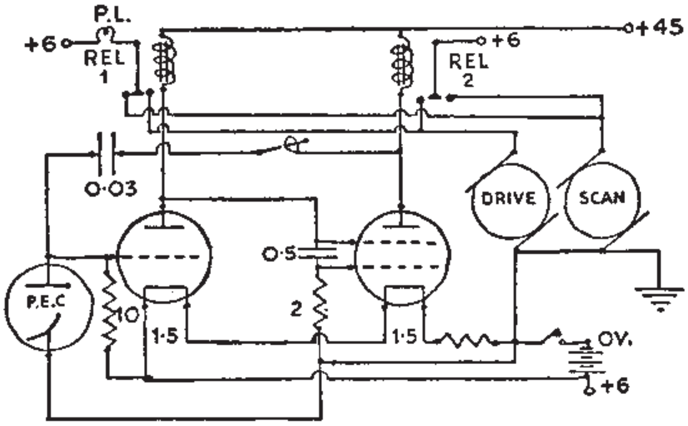


**Figure 3.7.** The brain of the tortoise. Source: Walter 1953, 289, fig. 22.

around when it picked up a light.[12] This interpretation found some empirical support. As Walter noted (1953, 109), "There was the curious coincidence between the frequency of the alpha rhythms and the period of visual persistence. This can be shown by trying how many words can be read in ten seconds. It will be found that the number is about one hundred—that is, ten per second, the average frequency of the alpha rhythms" (Walter 1953, 109). He also mentioned the visual illusion of movement when one of a pair of lights is turned off shortly after the other. Such data were at least consistent with the idea of a brain that lives not quite in the instantaneous present, but instead scans its environment ten times a second to keep track of what is going on.[13]

From a scientific perspective, then, the tortoise was a model of the brain which illuminated the go of adaptation to an unknown environment—how it might be done—while triangulating between knowledge of the brain emanating from EEG research and ideas about scanning.

## Tortoise Ontology

We can leave the technicalities of the tortoise for a while and think about ontology. I do not want to read too much into the tortoise—later machines and systems, especially Ashby's homeostat and its descendants, are more ontologically interesting—but several points are worth making. First, the assertion that the tortoise, manifestly a machine, had a "brain," and that the functioning of its machine brain somehow shed light on the functioning of the human brain, challenged the modern distinction between the human and the nonhuman, between people and animals, machines and things. This is the most obvious sense in which Walter's cybernetics, like cybernetics more broadly, staged a nonmodern ontology.[14] Second, we should reflect on the way the tortoise's brain latched onto its world. The tortoise is our first instantiation of the performative perspective on the brain that I introduced in chapter 1, the view of the brain as an "acting machine" rather than a "thinking machine," as Ashby put it. The tortoise did not construct and process representations of its environment (à la AI robotics); it did things and responded to whatever turned up (cycloidal wandering, locking onto lights, negotiating obstacles). The tortoise thus serves to bring the notion of a performative brain down to earth. In turn, this takes us back to the notion of Black Box ontology that I introduced in chapter 2. The tortoise engaged with its environment as if the latter were a Black Box, in Ashby's original sense of this word—a system to be performatively explored.[15] As ontological theater, the tortoise staged a version of this Black Box ontology, helping us to grasp it and, conversely, exemplifying a sort of robotic brain science that might go with such an ontology.

Now we come to the complication I mentioned in chapter 2. In one sense the tortoise staged a nonmodern Black Box ontology, but in another it did not. For Walter, the point of the exercise was to open up one of these boxes, the brain, and to explore the inner go of it in the mode of modern science. How should we think about that? We could start by remembering that in Walter's work the world—the tortoise's environment—remained a Black Box. In this sense, Walter's cybernetics had a hybrid character: nonmodern, in its thematization of the world as a performative Black Box; but also modern, in its representational approach to the inner workings of the brain. My recommendation would then be to pay attention to the nonmodern facet of this hybrid, as the unfamiliar ontology that cybernetics can help us imagine. But there is more to think about here. The question concerns the extent to which Walter's brain science in fact conformed to the stereotype of modern science. As I mentioned in chapter 2, cybernetic brain science was an odd sort of science in several ways. First, the scientifically understood brain had as its necessary counterpart the world as an unopened Black Box, so that the modern and the nonmodern aspects of this branch of cybernetics were two sides of a single coin. Second, the style of scientific explanation here is what I called "explanation by articulation of parts." Walter's brain science did not emulate physics, say, in exploring the properties of the fundamental units of the brain (neurons or their electromechanical analogues); instead, it aimed to show that when simple units were interconnected in a certain way, their aggregate performance had a certain character (being able to adapt to the unknown). Again, this sort of science thematizes performance rather than knowledge of individual parts. And third, this style of explanation had a tendency to undermine its own modern impulse in what I call the cybernetic discovery of complexity, to which we can now turn.

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IT IS ONE OF THE INTERESTING CONSEQUENCES OF THIS KIND OF MODEL-MAKING—THOUGH I ONLY REALISED IT AFTER I STARTED MAKING THESE TOYS—THAT A VERY SMALL NUMBER OF NERVE ELEMENTS WOULD PROVIDE FOR AN EXTREMELY RICH LIFE.

**GREY WALTER**, "PRESENTATION" (1971 [1954], 29)

The tortoises were simple and comprehensible artifacts. Anyone could understand how their two-neuron brains worked—at least, anyone familiar with the relay and triode circuits of the time. But, as Walter argued, "the variation of behaviour patterns exhibited even with such economy of structure are complex and unpredictable" (1953, 126). He noted, for example, that he had been taken by surprise by the tortoises' mirror and mating dances (1953, 130). The tortoises engaged with their environments in unexpected ways, displaying *emergent properties* relative to what Walter had designed into them. After the fact, of course, Walter explained such performances in terms of the tortoises' running lights, as mentioned above. But it is worth recognizing that such interpretations were themselves not beyond dispute. On the basis of his own tortoise reconstructions, Owen Holland (2003, 2101–8) was led to challenge Walter's interpretation of the source of these dances, arguing that they are a function of the oscillatory behavior set in motion by physical contact, rather than anything to do with the running lights. Here it begins to become clear that the tortoises remained mini–Black Boxes. As Walter put it, "Even in the simple models of behaviour we have described, it is often quite impossible to decide whether what the model is doing is the result of its design or its experience" (1953, 271).[16]

The tortoise thus again appears as ontological theater, but in a different sense from that discussed above. As a piece of engineering, it displayed the fact that a reductive knowledge of components does not necessarily translate into a predictive understanding of aggregate performance—one still has to run the machine and find out what it will do. As I said in chapter 2, I find this ontologically instructive too. Many people, including me, tend to think that the world has some determinate structure that is, in principle, fully comprehensible. What the tortoise stages us for us is that, even if that were true, we might still have to find out about the world in real-time performative interaction. For such people, it might be helpful to start by imagining the world as full of tortoiselike entities—unknowable in any predictive sense and always capable of surprising us, as the tortoise proved to be. This is another way to begin getting the hang of the ontology of cybernetics.

In his first publication on the tortoises, in *Scientific American* in May 1950, Walter (1950a, 44) emphasized this discovery of complexity in a striking extrapolation beyond the two-neuron tortoise brain: "It is unlikely that the number of perceptible functional elements in the brain is anything like the total number of the nerve cells; it is more likely to be of the order of 1,000. But even if it were only 10, this number of elements could provide enough variety for a lifetime of experience for all the men who ever lived or will be born if mankind survives a thousand million years." At stake here are not Walter's precise numbers (see Walter 1953, 118–20, for the calculation)—though cybernetic combinatorics readily generates enormous numbers, as we will see later. Walter was *not* suggesting that given ten elements he could predict the future of the human race in classically scientific fashion. His point concerned, rather, I think, the unimaginable richness of performance that could be generated by a few simple parts articulated with one another. Even if we knew what the ten functional elements of the brain are and how they are interconnected, we would not be able to "solve" the system and thus calculate and predict all possible forms of human behavior over the next billion years. We would just have to build the system and run it, like the tortoise, to see what it would do—or we could just let history run its course and find out. In general, even if we know all that there is to know about the primitive components of a Black Box, we might still not know anything about how the ensemble will perform. At this level of aggregation, the box remains black, and this is what Walter learned from his tortoises.

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Thus my sense of the tortoise as ontological theater—as variously conjuring up and playing out an ontological vision of performance and unknowability. We will see this ontology elaborated in all sorts of ways in the pages to follow. But here I should note two qualifications concerning just how much the tortoise can enlighten us. First, the tortoise was indeed adaptive, but only to a degree. Especially, it had *fixed goals* hard wired into it, such as pursuing lights. The tortoise did not evolve new goals as it went along in the world. This fixity of goals was a common feature of early cybernetic engineering, going back all the way to the steam-engine governor (which sought to keep the engine speed constant) and beyond. As ontological theater this has to be seen as a shortcoming. There is no reason to think that human beings, for example, are characterized by a fixity of goals, and every reason, in fact, to argue against it (Pickering 1995). From this angle too, then, we should see the tortoise as staging a hybrid ontology, part adaptive and part not.[17] As I have said before, the adaptive aspects of cybernetics are what I want most to get into focus here, as pointing toward the unfamiliar aspects of nonmodern ontology.

The tortoise's *world* also left something to be desired. It was a world that, to a first approximation, never changed, a fixed array of lights and obstacles. The tortoise adapted to its environment, but the environment did nothing in response.[18] There was no place for a dance of agency between the tortoise and its world. This has to be regarded as another shortcoming of Walter's cybernetics as ontological theater, and we can see in later chapters how other cybernetic systems, beginning with Ashby's homeostat, transcended this limitation.

## Tortoises as Not-Brains

IT IS UP TO M. WALTER TO EXPLAIN THE IMPORTANCE OF HIS MODELS FOR PHYSIOLOGY. THE ENGINEER IS INTERESTED IN THE MACHINE THAT IMITATES SENSE ORGANS AND THE MACHINE THAT LEARNS. ONE CAN IMAGINE A DAY WHEN MACHINES THAT LEARN WOULD HAVE A GENERAL IMPORTANCE IN INDUSTRY. THAT IS WHY WE HAVE REPEATED HIS APPROACH.

**HEINZ ZEMANEK**, "LA TORTUE DE VIENNE ET LES AUTRES TRAVAUX CYBERNÉTIQUES" (ZEMANEK 1958, 772, MY TRANSLATION)

In the opening chapter I mentioned the protean quality of cybernetics, that although the brain was its original referent, the brain could not contain it, and I can elaborate on that remark now. I have shown how the tortoise took shape as a model of the brain and as a contribution to brain science; I will shortly explore its specific connection to psychiatry. But one did not have to see a brain when contemplating a tortoise. One could simply see a machine, an interesting example of a particular style of adaptive engineering, a robot. Here is Walter's own account of the origins of the tortoise from *The Living Brain* (1953, 125): "The first notion of constructing a free goal-seeking mechanism goes back to a wartime talk with the psychologist, Kenneth Craik. . . . When he was engaged on a war job for the Government, he came to get the help of our automatic [EEG] analyser with some very complicated curves he had obtained, curves relating to the aiming errors of air gunners. Goal-seeking missiles were literally much in the air in those days; so, in our minds, were scanning mechanisms. . . . The two ideas, goal-seeking and scanning, . . . combined as the essential mechanical conception of a working model that would behave like a very simple animal." Craik was a young experimental psychologist and protocybernetican, who died at the age of thirty-one in a bicycle accident in Cambridge on 18 May 1945, the last day of World War II in Europe. He was very much the British Wiener, even more heavily involved in military research into gun aiming and the like during the war, and there are clear echoes of Wiener's wartime work on autonomous weapons systems in this quotation from Walter.[19] And though there is no evidence that Walter ever sought to develop the tortoise for such purposes, if one wanted to find a *use* for it, an obvious thing to do would be to fix a gun next to the guiding photocell or fill its body with explosives detonated by the contact switch. And Walter was certainly well aware of such possibilities. At the end of his technical description of tortoise construction, he stated that "the model may be made into a better 'self-directing missile' by using two photocells in the usual way" (1953, 291–92).[20]

Walter's contribution to brain science was thus also a contribution to the history of engineering and robotics (on which more below). And beyond the technical realms of brain science and robotics, the tortoises also found a place in popular culture. They were not simply technical devices. Walter showed them off and people liked them. He demonstrated the first two tortoises, Elmer and Elsie, in public in 1949, though "they were rather unreliable and required frequent attention." Three of the tortoises built by Bunny Warren were exhibited at the Festival of Britain in 1951; others were demonstrated in public regularly throughout the 1950s. They appeared on BBC television (Holland 2003, 2090–91, gives an account and analysis of a 1950 BBC newsreel on the tortoises). Walter set them loose at a meeting of the British Association for the Advancement of Science, where they displayed a lively interest in women's legs (presumably attracted to the light-reflecting qualities of nylon stockings: Hayward, 2001b).

This popular appeal, in turn, manifested itself in at least two lines of subsequent development. One was an embryonic eruption into the toy market: a tortoise was sent to the United States after the Festival of Britain as the prototype for a line of transistorized children's toys—which never went into production, alas (Holland 1996, n.d.; Hayward 2001b). One can now, however, buy construction kits for devices which are clearly versions of the tortoise. Along another axis, the tortoise entered the world of science fiction and popular entertainment. In the BBC's long-running *Doctor Who* TV series, I find it hard to doubt that the tortoise was the model for K-9, the Doctor's robot dog (which looked just like a tortoise, with a small tail attached). One thinks also of the Daleks, with their sinister optical scanner, and my recollection is that the Daleks were first seen in an electronic readout from a human brain which itself took the form of a TV image—another imaginative version of the cybernetic notion of scanning. What should we make of this popular appeal? It derived, I assume, from the quasi-magical properties of tortoises I mentioned in chapter 1, as mechanical devices that behaved as if they were alive. We are back in the territory of the Golem and the Sorcerer's Apprentice, and a fascination with transgression of the boundary between the animate and the inanimate. This animation of the inanimate hangs together, of course, with the implementation of the cybernetic ontology just discussed: the tortoises appeared so lively just because of their autonomy and sensitivity to their environment.

Brain science, psychiatry, robotics, toys, TV sci-fi: these are some of the areas that the tortoises contributed to. This list starts to establish what I mean by the protean quality of cybernetics, and as the book goes on, we can extend it.

## The Social Basis of Cybernetics

THE MECHANICAL DESIGN [OF A TORTOISE] IS USUALLY MORE OF A PROBLEM THAN THE ELECTRICAL. . . . THERE IS NOT A GREAT CHOICE OF MOTORS; THOSE USED FOR DRIVING SMALL HOME-CONSTRUCTED MODELS ARE ADEQUATE BUT NOT EFFICIENT. . . . IT IS OFTEN ADVISABLE TO RE-BUSH THE BEARINGS. . . . THE GEAR TRAINS TO THE DRIVING AND SCANNING SHAFTS ARE THE MOST AWKWARD PARTS FOR THE AMATEUR CONSTRUCTOR. THE FIRST MODEL OF THIS SPECIES WAS FURNISHED WITH PINIONS FROM OLD CLOCKS AND GAS-METERS.

**GREY WALTER,** *THE LIVING BRAIN* (1953, 290–91)

SO MANY DISCOVERIES HAVE BEEN MADE BY AMATEURS THAT THERE MUST BE A SPECIAL STATE OF MIND AND A PHASE OF SCIENTIFIC EVOLUTION WHEN TOO MUCH KNOWLEDGE IS A DANGEROUS THING. COULD ONE SAY THAT AN AMATEUR IS ONE WHO DOES NOT KNOW HIS OWN IMPOTENCE?

**GREY WALTER,** "TRAPS, TRICKS AND TRIUMPHS IN E.E.G." (1966, 9)

I mentioned in the opening chapter that cybernetics had an unconventional social basis as well as an unfamiliar ontology, and here we can begin the investigation of the former. One point to bear in mind is that Walter did have a steady job throughout his working life, spending the thirty-one years prior to his scooter accident at the Burden Neurological Institute. As I said, however, his career there revolved around his EEG work and electrophysiological research more generally, and the question that I want to focus on here concerns the social basis for his cybernetics as exemplified by the tortoises.

In the quotation above on Craik and the origins of the tortoise, I skipped over a phrase, "long before the home study was turned into a workshop," which precedes "the two ideas, goal-seeking and scanning, had combined." Walter built the first tortoises at home, in his spare time.[21] Hence, for example, the practical advice to readers on tortoise construction just quoted. Walter's key contribution to cybernetics was, then, the work of an amateur, a hobbyist. And, as we will see, this was true of all four of our principals. In this sense, then, we can say that at its origins British cybernetics had *no social basis*. It emerged from nowhere as far as established fields and career paths were concerned. The cyberneticians and their projects were *outsiders* to established fields of endeavor.

Some discussion is appropriate here. First, it is worth emphasizing that the amateur and hobbyist roots of British cybernetics are a marker of its oddity: there was no obvious field for it to grow from. Perhaps the most likely matrix would have been experimental psychology (one thinks of Kenneth Craik) but in fact cybernetics did not originate there. Second, we should go back to the standard origin story of cybernetics, connecting it to Norbert Wiener's military research. There is, as I said in chapter 1, a contrast here between British and American cybernetics. As I have already indicated, the primary referent of Walter's tortoise work was not some piece of military technology such as Wiener's antiaircraft predictor; it was the brain. Walter always presented the tortoise precisely as a model brain, and though I just quoted him on the tortoise as a self-guided missile, this was a passing remark. And, of course, it makes sense that a brain researcher working at a neurological institute would have the brain rather than weapons systems on his mind.[22]

This, then, is the other origin story of cybernetics that I can develop further as we go on, the story of cybernetics as emerging from and as brain science rather than military research. This story requires some nuance, needless to say. Little research in the 1940s and 1950s was immune to military influence, and it was Craik, the British Wiener, who gave Walter the idea of scanning. Nevertheless, it would be misleading to try to center the story of British cybernetics on war; it is much more illuminating to focus on the brain.[23] That said, there is another connection to warfare that is worth mentioning, which in fact deepens the contrast with Wiener.

In the second Grey Walter Memorial Lecture, the veteran EEG researcher W. A. Cobb told a story of wartime shortages of equipment and of how he eventually obtained a special timer from the wreckage of a crashed Spitfire (Cobb 1981, 61). We can take this as iconic of the conditions under which British cybernetics developed. Wiener worked on a well-funded military project at the cutting edge of research at MIT, the very heart of the U.S. military-academic complex; like Cobb, Walter and the other British cyberneticians cobbled together their creations from the detritus of war and a couple of centuries of industrialization.[24] The electronic components of machines like the tortoise were availably cheaply as war surplus (Hayward 2001b, 300), and, as Walter said, other parts were salvaged from old clocks and gas meters. If Wiener's cybernetics grew directly out of a military project, Walter's was instead improvised in a material culture left over from the war.

One last remark on the origins of British cybernetics. Inescapably associated with the notions of the amateur and the hobbyist are notions of sheer pleasure and fun. Just as there is no reason to doubt that Walter intended the tortoises as a serious contribution to brain science, there is no reason to doubt that he had fun building them and watching them perform. This theme of having fun is another that runs through the history of British cybernetics and again presents a stark contrast with that of cybernetics in the United States, where the only fun one senses in reading the proceedings of the Macy Conferences is the familiar and rather grim academic pleasure of the cut and thrust of scholarly debate. The chairman of the meetings, Warren McCulloch (2004, 356), recalled: "We were unable to behave in a familiar, friendly or even civil manner. The first five meetings were intolerable. Some participants left in tears, never to return. We tried some sessions with and some without recording, but nothing was printable. The smoke, the noise, the smell of battle are not printable." Of the many conventional boundaries and dichotomies that British cybernetics undermined, that between work and fun was not the least.

We can turn from the origins of British cybernetics to its propagation. Walter made no secret of his hobby; quite the reverse: he publicized the tortoises widely, engaging with at least three rather distinct audiences which we can discuss in turn. The first audience was the general public. According to Owen Holland (2003, 2090), "by late 1949, Grey Walter was demonstrating Elmer and Elsie, the first two tortoises, to the press, with all the showmanship that some held against him," and the first major press report appeared in the *Daily Express* on 13 December 1949, written by Chapman Pincher. The BBC TV newsreel mentioned above followed in 1950, and so on. Outside the world of journalism, Walter himself wrote for a popular readership. The principal published technical sources on the tortoises are Walter's two articles in *Scientific American* in May 1950 and August 1951 and his 1953 popular book *The Living Brain*. These contributed greatly to the public visibility of Walter and the tortoises, but let me postpone discussion of substantive outcomes of this publicity for a while.

As an academic myself, I have tended to assume that the proper readership and home for a field like cybernetics would be a scholarly one. Walter did not publish any detailed accounts of the tortoises alone in the scholarly literature, but in the early 1950s they often featured as parts of his emerging account of the brain as otherwise explored in EEG research. A lecture delivered to a psychiatric audience published in January 1950, for example, began with a discussion of the tortoises (not named as such), their complexity of behavior, and the significance of scanning, before plunging into the details of EEG findings and their interpretation (Walter 1950b, 3–6). But it is also safe to say that the major impact of cybernetics was not centered on any established field. Historical overviews of twentieth-century psychiatry, for example (on which more shortly), make little or no mention of cybernetics (e.g., Valenstein 1986; Shorter 1997).[25] And one can see why this should have been. The combination of brain science and engineering made concrete in the tortoises was a strange one, both to the sciences of the brain (neurophysiology, EEG research, psychology, psychiatry) and, from the other direction, to engineering. To *do* any of these disciplines on the model of Walter and the tortoises would have required drastic shifts in practice, which are much harder to make than any simple shift in the realm of ideas.

This brings us to the third community with which Walter engaged, the nascent community of cyberneticians in Britain. The 1948 publication of Wiener's *Cybernetics* both put the word itself into circulation in Britain and helped crystallize the formation of a self-consciously cybernetic community there. On 27 July 1949 John Bates of the Neurological Research Institute of the National Hospital in London wrote to Walter as follows:

> Dear Grey,
>
> I have been having a lot of "Cybernetic" discussions during the past few weeks here and in Cambridge during a Symposium on Animal Behaviour Mechanisms, and it is quite clear that there is a need for the creation of an environment in which these subjects can be discussed freely. It seems that the essentials are a closed and limited membership and a post-prandial situation, in fact a dining-club in which conventional scientific criteria are eschewed. I know personally about 15 people who had Wiener's ideas before Wiener's book

> appeared and who are more or less concerned with them in their present work and who I think would come. . . .
>
> Besides yourself, Ashby [see the next chapter] and Shipton [Walter's colleague and collaborator at the Burden], and Dawson and Morton from here, I suggest the following:-

| | | |
|---|---|---|
| Mackay | - | computing machines, Kings Coll. Strand. |
| Barlow | - | sensory physiologist—Adrian's lab. |
| Hick | - | Psychological lab. Camb. |
| Scholl | - | Statistical Neurohistologist—U.C. Anat. lab. |
| Uttley | - | ex Psychologist, Radar etc. T.R.E. |
| Gold | - | ex radar zoologists at Cambridge |
| Pringle | | |

> I could suggest others but this makes 13. I would suggest a few more non neurophysiologists communications or servo folk of the right sort to complete the party but those I know well are a little too senior and serious for the sort of gathering I have in mind.
>
> We might meet say once a quarter and limit the inclusive cost to 5/- less drinks. Have you any reactions? I have approached all the above list save Uttley so far, and they support the general idea.

Walter replied the next day to this "exciting letter"—"We also have been having some pretty free CYBERNETIC discussions and your notion of a sort of Dining Club attracts me very much. I agree that it will be nice to keep the gathering rather small, about the size of a witches coven owing to the shortage of broomsticks." Walter also mentioned that Warren McCulloch was visiting Britain in September 1949 and suggested that this would provide a good occasion for the first meeting of the group.[26] And thus it came to pass. McCulloch addressed the first meeting of the Ratio Club on 14 September 1949 on the topic of "Finality and Form in Nervous Activity." Sixteen member were present, including Ashby but not Walter, "owing to the delivery of a male homeostat which I was anxious to get into commission as soon as possible." Expenditure on food was £1-4-0; on beer and wine, £7. Thereafter, the club met at least thirty-four times up to 1955 (with decreasing frequency after 1952) before being wound up at a reunion meeting on 27 November 1958.[27]

There is much that might be said on the Ratio Club, its membership, and their doings, but this would easily carry us too far afield, and I will confine myself to a few observations.[28] We should note first Ratio's interdisciplinarity. Bates described its proposed membership as "half primarily physiologists though with 'electrical leanings' and half communication theory and ex-radar folk with biological leanings" and, later, to Turing, as "half biologists—(mostly neurophysiologists) and half engineers and mathematicians," while remarking to himself that the club was "incomplete—no sociologists, northeners, professors" (Clark 2002, 78–80).[29] But beyond that, Ratio was interinstitutional, as one might say. It did not simply elide disciplinary boundaries within the university; it brought together representatives from different sorts of institutions: people from the universities, but also medical men and physiologists based in hospitals and research institutes, including Walter and Ashby, and workers in government laboratories (Albert Uttley at the Telecommunications Research Establishment, the TRE).[30] The Ratio Club was the center of gravity for work in cybernetics in Britain from 1949 to the mid-1950s, and it existed *transversely*, or orthogonally, to the usual institutions for the production of knowledge, cutting across not just academic disciplinary boundaries, but also across the usual institutional classifications, too. And this transversality continued to be a conspicuous feature of British and European cybernetics after the demise of Ratio, when the series of Namur conferences became the key institutional venue from 1956 onward.[31]

Two observations follow. First, ontology and sociology were entangled here. This transverse crystallization had the character of a purification that was at once social and ontological. From the side of traditional fields of practice, it would be a mistake to think that an interest in the adaptive brain was actively excluded. But the formation of first the Ratio Club and then the Namur conference series attests to a perceived marginality of the cyberneticians in their own fields, and a perceived closeness to workers in other fields with similar interests. From the other side, the shared interest in the adaptive brain came to center precisely on transverse institutions like the Ratio Club. Ratio—rather than their home disciplines and institutions—was where people like Walter found an active and engaged audience for their cybernetics. And, as we will see later, much of the propagation of cybernetics up the present has continued to be located in such strange antidisciplinary and interinstitutional spaces, even as the range of cybernetics has gone far beyond the brain.

My second observation is this. The Ratio Club and its successor institutions were undoubtedly successful in maintaining the postwar cybernetic ferment, but they were conspicuously lacking in the means of social reproduction. The Ratio Club had no mechanism for training students: a dining club does not grant PhD's. Among our cyberneticians, only Stafford Beer in the second generation seems to have taken this problem seriously, but we can note now that this ad hoc organization contributed importantly to the way cybernetics evolved. Academic disciplines are very good at holding neophytes to specific disciplinary agendas, and it was both a strength and a weakness of cybernetics that it could not do this—a strength, inasmuch as cybernetics retained an undisciplined and open-ended vitality, an ability to sprout off in all sorts of new directions, that the established disciplines often lack; a weakness, as an inability both to impose standards on research and to establish career paths for new cyberneticians left enthusiasts to improvise careers much as did the founders.

These remarks return us to a topic broached above. Popular writing and, in Walter's case especially, public performances assumed an importance in the propagation of cybernetics that one does not find in established fields. In doing the research for this book I have been surprised to discover just how many first and consequential contacts with cybernetics have been with popular books, articles and performances. We just saw that Wiener's *Cybernetics* was central to the crystallization of the British cybernetics community, and Beer fell into cybernetics after reading the same book. Walter's cybernetics traveled and mutated along the same lines. In chapter 7 we can discuss the adaptive architecture of John Frazer, who tried to build his own robots after seeing a display of the tortoises as a schoolboy, before falling in with Pask (who declared himself a cybernetician after meeting Wiener in person as an undergraduate). Later in this chapter, we can see how William Burroughs laundered elements of cybernetics into the counterculture after reading *The Living Brain*. And in the following section I want to bring the discussion of robotics up to the present by focusing on another *Living Brain* reader, Rodney Brooks.[32] The general point to note here, however, is that the propagation of cybernetics was indeed both unsystematic and undisciplined. Walter's cybernetics was addressed to the brain, but Brooks understood it as robotics, Frazer took it into architecture, and Burroughs transplanted it into the domain of altered states and that classic sixties project, the exploration of consciousness. Hence the protean quality of cybernetics, with individuals free to adapt it to their own interests and obsessions, unconstrained by disciplinary policing.[33]

## Rodney Brooks and Robotics

Rodney Brooks is currently director of the MIT Computer Science and Artificial Intelligence Laboratory, Panasonic Professor of Robotics at MIT, and past chairman and now chief technical officer of iRobot Corporation.[34] Brooks began his career in robotics as a schoolboy in Australia when "I came across a Pelican edition of Grey Walter's book, and tried to build my own version of *Machina Speculatrix*, using transistor technology rather than vacuum tubes. . . . The subtleties of the original electronics were a little beyond me, but I did manage to get my first robot, Norman, to the point where it could wander around the floor, respond to light, and bumble its way around obstacles" (Brooks 2002, 27). From Australia he moved to the United States, completed a PhD in computer science at Stanford University in 1981, and held postdoctoral positions at Carnegie Mellon University and MIT and a faculty position at Stanford, before rejoining MIT as an assistant professor in 1984. The first machine that Brooks and a few collaborators then constructed was a robot called Allen, which made Brooks's reputation, in certain quarters at least, and began his rise to his current position as leader of one of the most important computer science and AI laboratories in the world. And the point to grasp is that Allen was very much an updated version of the tortoise. Using a ring of twelve sonar range detectors in place of the tortoise's photocell and contact switch, and solid-state logic elements instead of electronic valves, Allen would explore its environment, pursuing goals (such as finding and trying to get to the most distant part of the room) and avoiding obstacles along the way. Even Brooks's construction strategy, which he called a "subsumption architecture," getting different layers of the control system working one after the other, mirrored Walter's transit from the tortoise itself to CORA (see below).[35]

So, if one is looking for a "weighty" answer to the question, what happened to cybernetics? one answer would be: it is alive and well in Brooks's lab at MIT. But then another question arises. How on earth could one make a reputation in computer science by building an updated tortoise thirty-six years after Walter? Of course, Brooks displayed his own originality, but some important history is needed here, which I want just to mention without going into detail. In the opening chapter I contrasted the performative brain of cybernetics with the representational one of AI, and I need to say a little about the development of the latter field.

The canonical history of AI dates its self-conscious inception to the six-week workshop "Artificial Intelligence" at Dartmouth College organized by John McCarthy in 1956 (Brooks 2002, 21–31). Many of the principles of the nascent field were present, and what followed was a rapid purification, as I called it above, but going in the opposite direction. From World War II to the mid-1950s speculation about the mind in terms of machine models was an exceptionally rich, diverse, and fascinating field, in which cybernetics in many ways took the lead. From the mid-1950s onward a representationalist strand of AI came to the fore, and it achieved institutional dominance within the space of about ten years. In GOFAI—good, old-fashioned AI—the aim was to mimic mental performances. Alan Newell and Herbert Simon's Logic Theorist program was an early landmark, and it was a program that mimicked the proofs to be found in Bertrand Russell and Alfred North Whitehead's *Principia Mathematica*. In robotics this translated into the problematic of generating computer representations (maps, models) of environments and operating on them to execute plans, such as moving from A to B while avoiding obstacles. This style of AI and robotics, then, can stand as a piece of ontological theater for the other ontology from that of cybernetics, the modern ontology of knowability. AI robots sought to know their worlds substantively, and to accomplish their goals through that knowledge. AI robotics was the other to Walter-style robotics.

Historically, representational, or symbolic, AI quickly became the dominant paradigm in the universities, largely displacing cybernetics from its already tenuous foothold, not only from computer science departments and their ilk, but from social science departments, too, in the so-called cognitive revolution, in which human mental powers were conceived by analogy to digital computers as information processors (Gardner 1987). Of course, the rise of AI and the associated "cognitive sciences" is an immense historical story in itself, but let me just comment briefly. How did AI come to exert such a fascination over the academic and popular imagination? Part of the answer must lie in its very familiar ontology. It is easy to think of the brain and mind as the organ of knowledge, and AI thus conceived presents a straightforward problem of mimicking very familiar (especially to academics) mental performances. At the same time, AI was uniquely associated with digital computers and their programming and thus fitted very naturally into the agenda of novel postwar departments of computer science (unlike the odd machines of Walter et al.). And third, the military bought it. Almost all the funding for AI research was provided by the U.S. military, and almost all of that went to research in symbolic AI (Edwards 1996).[36]

Cybernetics thus lost much of its social basis in the universities from the mid-1950s onward; the cyberneticians became even more marginal there than they had been before—which is another kind of answer to the question, what happened to cybernetics? But this gets us back to the story of Rodney Brooks. In robotics, symbolic AI promised much but never quite delivered. Machines were never quite fast enough to accomplish real-time control.[37] In his first years in the United States, Brooks worked within this tradition, focusing on computer models of environments, but became increasingly frustrated with it. In the late 1970s at Stanford, he helped Hans Moravec, a future leader in

AI-style robotics, on a robot which moved so slowly (due to the time taken for computation) that, outdoors, the movement of sun and shadows would confuse its internal repesentations (Brooks 2002, 30):

> Despite the serious intent of the project, I could not but help feeling disappointed. Grey Walter had been able to get his tortoises to operate autonomously for hours on end, moving about and interacting with a dynamically changing world and with each other. His robots were constructed from parts costing a few tens of dollars. Here at the center of high technology, a robot relying on millions of dollars of equipment did not appear to operate nearly as well. Internally it was doing much more than Grey Walter's tortoises had ever done—it was building accurate three-dimensional models of the world and formulating detailed plans within those models. But to an external observer all that internal cogitation was hardly worth it.

It was against this background that Brooks's 1985 robot, Allen, stood out as a revolutionary alternative. Allen dispensed with the "cognitive box" (Brooks 2002, 36) that was the hallmark and center of attention in contemporary robotics in favor of the performative and adaptive engagement with the environment that was the hallmark of the tortoises.[38] This, of course, put him on the wrong side of the law as far as the academic establishment was concerned, and he has repeatedly told the story of how, during his first scholarly presentation of his new approach, one senior computer scientist whispered to another, "Why is this young man throwing away his career?" Three referees unanimously recommended rejection of his first paper on this approach—though it was published anyway (Brooks 1999 [1986]) and went on to become "one of the most highly cited papers in all of robotics and computer science" (Brooks 2002, 43). In the event, though the "arguments . . . continue to today" (Brooks 2002, 43), Brooks's approach did succeed in redirecting the work of a substantial fraction of the robotic community back into Walterian, cybernetic channels. One token of this success came in 2002, with the organization of a major international conference, "Biologically-Inspired Robotics," held at the Hewlett-Packard Laboratory near Bristol and close to the Burden Institute. Marking the twenty-fifth anniversary of Walter's death, the subtitle of the conference was simply "The Legacy of W. Grey Walter." Many of the principals of this "new" field" gave invited addresses, and graduate students presented an impressive array of talks.[39]

After a decades-long hiatus, then, at Brooks's lab at MIT, and many other academic centers, too, the robotic wing of cybernetics finally gained what it conspicuously lacked in its formative years, a solid institutional base not only for research but also for social reproduction, the training of graduate students as future researchers with a prospect of recognizable career paths in the field.[40] And one concluding remark is worth making for future reference. In the following chapters we will encounter many imaginative initiatives in cybernetics which eventually fizzled out, and one inevitably wonders whether this points to some essential flaw in cybernetics itself. I think we should remember that Walter's robotics once fizzled out, but that in retrospect it is clear that the fizzling had more to do with the lack of an institutional base and support than any inherent flaws.[41]

## CORA and *Machina docilis*

AFTER FOUR YEARS [IN CAMBRIDGE] SPENT LITERALLY IN A CAGE AND CHAINED BY THE ANKLE—NOT FOR PUNISHMENT BUT FOR ELECTRICAL SCREENING—. . . IMAGINE, THEN, HOW REFRESHING AND TANTALIZING WERE THE RESULTS FROM PAVLOV'S LABORATORY IN LENINGRAD TO THOSE ENGAGED ON THE METICULOUS DISSECTION OF INVISIBLE NERVE TENDRILS AND THE ANALYSIS OF THE IMPULSES WHICH WE INDUCED THEM TO TRANSMIT.

**GREY WALTER**, *THE LIVING BRAIN* (1953, 51)

The tortoise served as a model of the adaptive brain, but only a primitive one. It lived in real time, reacting to environmental cues (lights, contacts) as they happened to it and never learning anything from its experience. Walter quickly sought to go beyond this limitation by building in a second layer of adaptability, and he concluded his first publication on the tortoise by mentioning that the "more complex models that we are now constructing have memory circuits" (1950a, 45). These more complex models entailed two modifications to the basic tortoise. One was to equip it with more senses—wiring a microphone into its circuits, for example, to give it a sensitivity to sound as well as light. The other was the addition of a clever circuit called CORA, for conditioned reflex analogue (figs. 3.8, 3.9). Wired into the tortoise, CORA converted *Machina speculatrix* to *Machina docilis*, as Walter called it—the easily taught machine. CORA detected repeated coincident inputs in different sensory channels and, when a certain threshold of repetition was reached, opened up a link from one sense to the other—so that the tortoise would become "conditioned" to react to a sound, say, in the way that it had hitherto reacted to the contact switch on its body.[42]

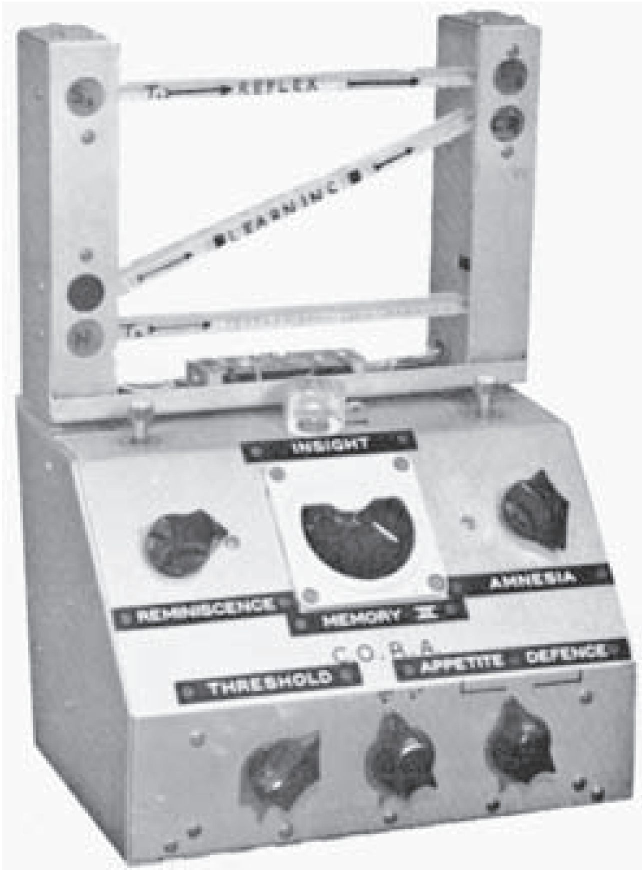


**Figure 3.8.** CORA. Source: de Latil 1956, facing p. 51.

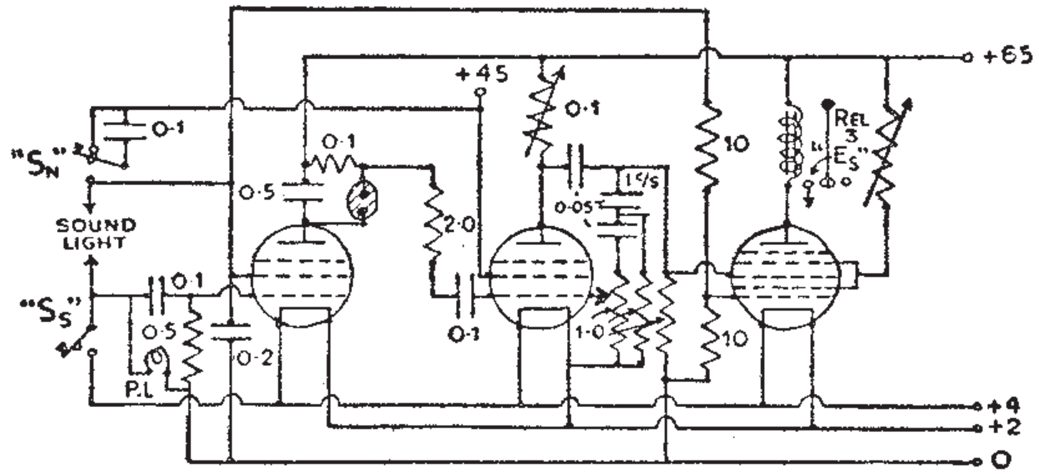


**Figure 3.9.** CORA: circuit diagram. Source: Walter 1953, 295.

What can we say about CORA? As its name implies, CORA was intended to emulate classical Pavlovian conditioning in animals. As a student at Cambridge, Walter had worked with a student of Pavlov for more than a year to set up a conditioning laboratory, "mastering the technique and improving it by the introduction of certain electronic devices." When "the great" Pavlov himself visited England, Walter, "as the English exponent of his work . . . had the privilege of discussing it with him on familiar terms. . . . I asked him if he saw any relation between the two methods of observing cerebral activity, his and Berger's [EEG readings]. . . . But Pavlov showed no desire to look behind the scenes. He was not in the least interested in cerebral mechanisms" (Walter 1953, 51–52).[43] CORA, in contrast, was explicitly a further scientific attempt to look behind the scenes, to open up the Black Box of the adaptive brain by building a model that could mimic its performances, just like the tortoises before that.

CORA did, indeed, make a connection between the electrical rhythms of the brain and conditioned learning. The key element in connecting one sense to another was precisely the build up of an oscillating voltage in CORA, and Walter laid much store by this, even arguing that CORA displayed the contingent negative variation in electrical potential which was his most important contribution to neurophysiology (1966, 13), but I cannot explore this further here.[44] Instead, I want to comment on CORA as brain science from several angles before connecting it to Walter's psychiatric milieu.

Reversing the earlier order, I begin with a quick comment on the relation of CORA to the social basis of cybernetics. CORA was a virtuoso piece of electrical engineering, in both its design and construction. The tortoise was imitable—by Frazer, Brooks, and many others—but CORA was inimitable. I know of no attempts to replicate it, never mind take the development of the tortoise beyond it.[45] Even Walter discontinued his robotics after CORA. *Machina speculatrix* pointed to a difficult but, to some—odd schoolboys like Frazer and Brooks; contributors to the Namur conferences—manageable synthesis of brain science and engineering. *Machina docilis* upped the ante too far. Nothing grew specifically from it in the cybernetic tradition. In the late 1980s revival of Walter-style robotics, machines that learned were indeed built, but that learning was based on neural networks, not CORA-style electronics, and the oscillatory features that intrigued Walter were lost (at least, temporarily). In that sense, CORA remains an unexploited resource in the history of cybernetics.

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CORA also invites us to extend the discussion of cybernetic ontology to encompass epistemology. The great novelty of *M. docilis* was that it acquired a sort of knowledge about the world: it learned what to associate with what. How should we think about that? The point I would emphasize is that the knowledge of *M. docilis* waxed and waned with its performance, integrating over its experience—associations between stimuli would be lost if the robot's expectations did not continue to be reinforced—and thus functioned as a heuristic guide, emerging from and returning to performance, not as any kind of controlling center. *Docilis* thus offers us a vision of knowledge as engaged in, and as part of, performance, rather than as a thing itself or as some sort of external determinant of action—a vision of knowledge as being *in the plane of practice*, as I put it in *The Mangle of Practice*, not above it. Much as *speculatrix* acted out for us a performative ontology, then, *docilis* also staged a performative epistemology, as I called it in chapter 2—an appreciation of knowledge not as a hopefully definitive mapping of the world, but as another component of performance. This is the vision of knowledge that goes with the cybernetic ontology, and that we will see elaborated in succeeding chapters.[46]

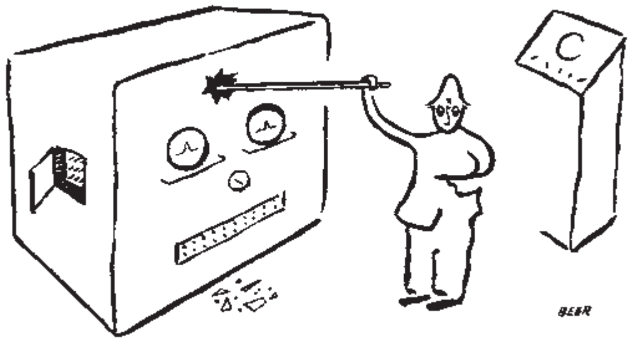
## Cybernetics and Madness

PSYCHIATRISTS USED TO BE REPROACHED WITH THEIR LACK OF THERAPEUTIC ZEAL; IT WAS SAID THEY WERE RESIGNED WHEN THEY SHOULD HAVE BEEN HOPEFUL AND ENTERPRISING, AND TORPID WHEN ENERGY WAS CALLED FOR. WHETHER THE REPROACH WAS DESERVED OR NOT IT SEEMS TO HAVE STUNG THEM INTO THERAPEUTIC FURY. CONTINUOUS NARCOSIS, INSULIN SHOCK AND CARDIAZOL FITS HAVE PROVED THAT THE PSYCHIATRIST IS AT LEAST AS DARING AS THE SURGEON NOWADAYS. THE PAPERS BY KALINOWSKY IN OUR ISSUE OF DEC. 9, AND BY FLEMING, GOLLA AND WALTER IN THIS RECORD ANOTHER BOLD STEP. . . . BUT WE MUST NOT LET UNCONSCIOUS ASSOCIATIONS WITH WHAT IS DONE PERIODICALLY IN A ROOM AT SING SING PREJUDICE US AGAINST WHAT MAY WELL TURN OUT TO BE A VALUABLE STEP FORWARD.

**EDITORIAL**, "MORE SHOCKS," *LANCET, 234*, NO. 6070 (30 DECEMBER 1939): 1373

It is tempting to think of the tortoises and CORA as freestanding scientific and engineering projects, divorced from mundane concerns. Walter may have mentioned the tortoise's potential as an autonomous weapons system, but he did nothing to pursue it. On the other hand, one of the first things he did with CORA was drive his tortoises mad. This points to connections between his cybernetics and psychiatry that we can explore.

If the CORA-equipped tortoise could be understood as a model of a normal brain, Walter was keen to show that it was a model for the pathological brain too. In his first article on the tortoise, Walter (1950a, 45) noted that, with




'Prefrontal leucotomy, Sir . . .'

**Figure 3.10.** "Prefrontal lobotomy, Sir . . . ." Source: Beer 1994a, 162. (Courtesy of Cwarel Isaf Institute and Malik Management Zentrum St. Gallen [www.management.kybernetik.com, www.malik-mzsg.ch].)

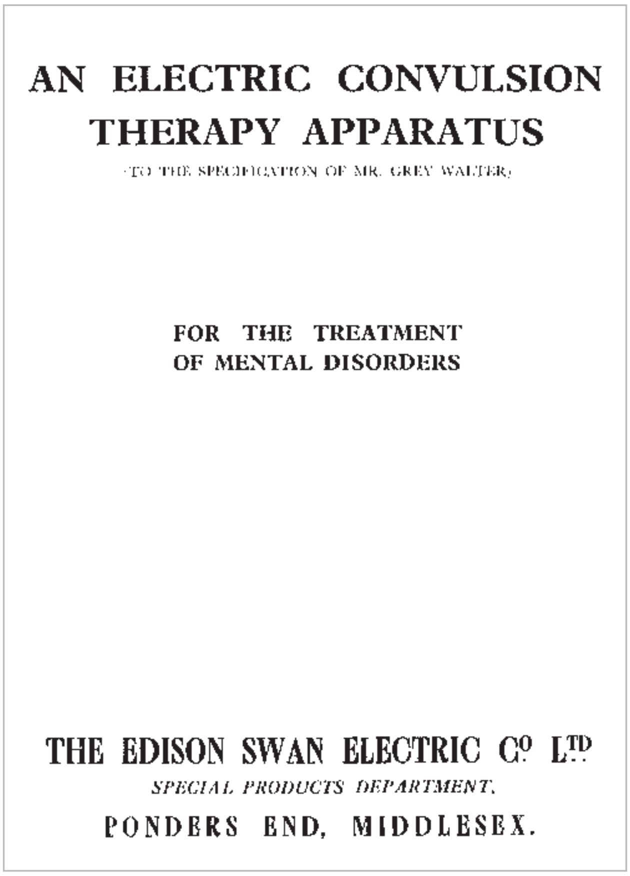
CORA, "the possibility of a conflict neurosis immediately appears," and in a follow-up article in August 1951 he observed that (63) "it becomes only too easy to establish an experimental neurosis. Thus if the arrangement is such that the sound becomes positively associated both with the attracting light and with the withdrawal from an obstacle, it is possible for both a light and a sound to set up a paradoxical withdrawal. The 'instinctive' attraction to a light is abolished and the model can no longer approach its source of nourishment. This state seems remarkably similar to the neurotic behavior produced in human beings by exposure to conflicting influences or inconsistent education." Or, as he put it more poetically in *The Living Brain* (1953, 183), "in trying, as it were, to sort out the implications of its dilemma, the model ends up, 'sicklied o'er with the pale cast of thought,' by losing all power of action."[47]

The idea that mental problems might be precipitated by conflicting patterns of conditioning was not original to Walter. As he acknowledged, its history went back to the induction of "experimental neuroses" in dogs by clashing conditioning regimes, carried out in the laboratory of "the master," Pavlov himself, in 1921 (Gray 1979, 119; Pavlov 1927).[48] And in March 1950, for example, two months before Walter's first tortoise article appeared, *Scientific American* featured an article entitled "Experimental Neuroses" by Jules Masserman, a psychiatrist at Northwestern University, which discussed the induction of pathological symptoms by cross-conditioning in cats. Drawing upon Auguste Comte's typology, Masserman argued that the experimentalization of neuroses moved psychiatry from the "mystic" and "taxonomic" stages into the ultimate "dynamic" phase of "science" (Masserman 1950). Walter could have made the same point about his experiments with CORA. And one could say he had gone one step beyond Masserman. Not content with simply demonstrating that cross-conditioning could produce pathological behavior, he had, again, produced an electromechanical model which enabled one to grasp the go of this process at the hardware level.

It is thus revealing to think of cybernetics as a science of psychiatry, not in the sense that it could be reduced to psychiatry—even with the tortoise it already overflowed the bounds of the brain—but in the sense that psychiatry was a surface of emergence (Pickering 2005b) for cybernetics: Walter's cybernetics (and Ashby's) grew out of the phenomena and problematics of his psychiatric milieu. And we can take this line of thought further in a couple of directions. One is to note that after driving his tortoises mad, Walter cured them (1953, 184): "When a complex learning model develops an excess of depression or excitement, there are three ways of promoting recovery. After a time the conflicting memories may die away—except in obsessional states. . . . Switching off all circuits and switching on again clears all lines and provides, as it were, a new deal for all hands. Very often it has been necessary to disconnect a circuit altogether—to simplify the whole arrangement." And in case his readers missed the point, Walter went on to analogize these electromechanical procedures to those of psychiatric therapy, adding his cybernetic apologia for the latter:

> Psychiatrists also resort to these stratagems—sleep [leaving the machine alone for a long time], shock [switching it off and on again] and surgery [disconnecting electrical circuits within it]. To some people the first seems natural, the second repulsive, and the third abhorrent. Everyone knows the benison of sleep, and many have been shocked into sanity or good sense, but the notion that a mental disorder could be put right by cutting out or isolating a part of the brain was an innovation which roused as much indignation and dispute as any development in mental science. There are volumes of expert testimony from every point of view, but our simple models would indicate that, insofar as the power to learn implies the danger of breakdown, simplification by direct attack may well and truly arrest the accumulation of self-sustaining antagonism and "raze out the written troubles of the brain."

So cybernetics was a science of psychiatry in a double sense, addressing the go of both mental disorder and psychiatric therapy and offering a legitimation of the latter along the way. And since Walter does not use the usual terms for the therapies he mentions, we should note that we are plunged here into the


AN ELECTRIC CONVULSION
THERAPY APPARATUS
(TO THE SPECIFICATION OF MR. GREY WALTER)

FOR THE TREATMENT
OF MENTAL DISORDERS

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PONDERS END, MIDDLESEX.

**Figure 3.11.** ECT brochure, cover page. Source: Science Museum, London, BNI archive.

"great and desperate cures"—insulin shock, chemical shock, electroshock (electroconvulsive therapy—ECT), and lobotomy—that arose in psychiatry in the 1930s and had their heyday in the 1940s and early 1950s, the same period as the first flush of cybernetics.[49]

And to put some more flesh on this connection, we should note that despite his evident desire to "do science" as he had in his student days at Cambridge, Walter continually found himself entangled with the concerns of the clinic. During his brief stint in London, he wrote in a 1938 report to the Rockefeller Foundation on his EEG work (1938, 16) that "the volume of clinical work which I have been asked to undertake has grown to embarrassing proportions. . . . These examinations are, of course, undertaken most willingly . . . but the clerical and other routine work, to say nothing of the maintenance of apparatus . . . take up so much time that little is left for breaking new ground."[50] Walter's later work on flicker (see below) also had a significant clinical element. But more directly to the point here is that the newly established Burden Neurological Institute took the lead in transplanting the new approaches to psychiatry to Britain, claiming an impressive list of firsts, including the first use of ECT in Britain in 1939 and the first prefrontal leucotomy in 1940 (Cooper and Bird 1989). And Walter was very much involved in these achievements. His technical skill and creativity were such that he had a standing relationship with the Ediswan Company in the development of commercial apparatus, and Britain's first commercial ECT machine was developed by Ediswan and carried on the title page of its brochure the statement that it was built "to the specification of Mr. Grey Walter" (fig. 3.11).[51] Walter was one of the authors of the first three papers to appear from the Burden on ECT. The earliest of these appeared in the *Lancet* in December 1939 (Fleming, Golla, and Walter 1939), describes ECT as EEG in reverse, and includes EEG readings of two post-ECT patients.[52] During World War II Walter himself performed ECT treatments on American soldiers suffering from "battle fatigue."[53]

Walter's interest in mental pathologies and therapies was thus by no means that of a detached observer, and if one wanted to identify the worldly matrix from which his cybernetics emerged, it would have to be psychiatry; more specifically the psychiatry of the great and desperate cures; and more specifically still the world of electroshock, electroconvulsive therapy, ECT.[54]

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Two remarks to end this section. In chapter 1 I said that it was interesting to think of cybernetics as one of Deleuze and Guattari's "nomad sciences" that destabilize the state, and we can come back to that thought now. Earlier in the present chapter I described the nomadic wandering of Walter's cybernetics through inter- and antidisciplinary worlds such as the Ratio Club and the Namur conferences, and yet when it came to real-world psychiatry Walter's work was evidently no threat to the established order. What should we make of this? The obvious remark is that Walter's cybernetics was adjusted to his professional career in a double way: its radical aspects flourished outside psychiatry's gates, and within those gates it was domesticated to conform to the status quo. There is no need to be cynical about this: in the forties and early fifties it was possible to be optimistic about the great and desperate psychiatric cures (compared with what had gone before), and there is no reason to doubt that Walter (and Ashby) were genuinely optimistic. Nevertheless, we can also see how ontology and sociology were correlated here. As will become clearer in chapter 5 when we discuss Bateson and Laing, it was possible to go much further than Walter in developing the cybernetic theme of adaptation in psychiatry, but the price of this was a transformation of the social relations of doctors and patients that did, in a Deleuzian fashion, threaten the established order.

Second, it is interesting to ask where this line of first-generation cybernetic psychiatry went. The answer is: nowhere. In Britain, Walter and Ashby were the leading theorists of mental pathology and therapy in the forties and fifties, with their models offering a new understanding of the brain, madness, and its treatment, but histories of twentieth-century psychiatry give them hardly a mention (try Valenstein 1986 and Shorter 1997). And one can think of several reasons why this should be. The first takes us back to the sheer oddity of cybernetics. Walter remained to a significant degree an outsider to psychiatry in his specifically cybernetic work, and it was also the case that Walter's cybernetics made little constructive contribution to psychiatric therapy—it offered an explanation of the mechanisms of ECT and lobotomy without suggesting new therapeutic approaches. Again, one might imagine that Walter had got as far as he could with CORA. It is not clear what his next step might have been in developing this line of research further, or where he could have found support for what would probably have been a significant engineering effort.

But beyond all that, we need to think about two broader developments bearing on psychiatry as a clinical field. The first was the introduction in the 1950s of psychoactive drugs that proved effective in controlling the symptoms of mental disorder, beginning with chlorpromazine (Shorter 1997, chap. 7; Rose 2003). These drugs had their own unfortunate side effects but did not entail the violence and irreversibility of lobotomy, which went into rapid decline in the mid-1950s. ECT enjoyed a longer history, up to the present, but its use also declined in the face of drugs, and the technique lost its cutting-edge, if I can say that, status as the most advanced form of psychiatric therapy.[55] Cybernetics was thus left high and dry in the later 1950s, as a science of clinical practices which were, if not entirely extinct, at least less prevalent than they had been in the 1940s. It is hardly surprising, then, that Walter found other lines of research more attractive from the mid-1950s onward. Ashby continued developing his own cybernetics as a science of psychiatry into the later 1950s, but, as we shall see, he too abandoned his psychiatrically oriented research from around 1960.

The other development we need to think about here is a growing critique in the 1950s of violent psychiatric therapies and even of the use of antipsychotic drugs, a critique which burst into popular consciousness in the 1960s as what was often called the antipsychiatry movement. This movement was not, despite the name, pure critique. It entailed a different way of conceptualizing and acting upon mental disorders, which was, as it happens, itself cybernetic. This gets us back to Bateson and Laing, and on to chapter 5.

## Strange Performances

For the remainder of this chapter I want to come at Walter's work from a different angle. The tortoises and CORA were Walter's most distinctive contribution to the early development of cybernetics, but they occupied him only in the late 1940s and early 1950s, and here we can examine some of his more enduring concerns with the brain—and how they crossed over into the counterculture of the sixties.

As I mentioned earlier, Walter's research career was centered on EEG work, and this, like the tortoises though in a different register, again thematized the brain as a performative organ. And the point we need to dwell on now is that, as I remarked in chapter 1, one can be *curious* about the performative brain in a way that a cognitive conception hardly invites. If one thinks about conscious mental operations, as in mainstream AI and the cognitive sciences, there is not much to be curious about. The task for AI is thus to model on a computer familiar cognitive feats like playing chess, solving equations, or logical deduction. In contrast, the performative brain is more of a challenge. We have little conscious access to processes of adaptation, for example. Who knows what a performative brain can do? This is a sense in which the brain appears as one of Beer's exceedingly complex systems, endlessly explorable. Finding out what the brain can do was a central aspect of Walter's research throughout his career, and we can examine some interesting aspects of that here.[56]

Walter's 1953 book *The Living Brain* is largely devoted to the science of the normal brain and its pathologies, epilepsy and mental illness. But in different passages it also goes beyond the pathological to include a whole range of what one might call altered states and strange performances: dreams, visions, synesthesia, hallucination, hypnotic trance, extrasensory perception, the achievement of nirvana and the weird abilities of Eastern yogis and fakirs—the "strange feats" of "grotesque cults" (1953, 148) such as suspending breathing and the heartbeat and tolerating intense pain.[57] What should we make of this?

1. It exemplifies the sort of curiosity about the performative brain that I just mentioned—this is a list of odd things that brains, according to Walter, can do.[58]

2. It conjures up an understanding of the brain as an active participant in the world. Even in the field of perception and representation, phenomena such as dreams and hallucinations might be taken to indicate that the brain does not copy the world but assimilates sensory inputs to a rich inner dynamics. The tortoise did not thematize this aspect of the brain (except, to

a limited degree, in its scanning mechanism), but it is part of what I tried to get at in chapter 2 by mentioning the work of Kauffman and Wolfram on the endogenous dynamics of complex systems, which we will see elaborated in in the following chapters.[59]

3. It is clear that Walter spoke with personal authority about some items on his list of strange performances, while others were abstracted from a more general awareness of other cultures, especially of the East, with India never all that far away in the British imagination. What strikes me about all of the items on the list is that they refer to aspects of the self that are devalued in modernity. We could think of the paradigmatic modern self in terms of the self-contained individual, dualistically opposed to other selves and the material world, a center of reason, calculation, planning, and agency; and measured against such a yardstick dreamers and madmen are defective selves. Or, to put the point more positively, it appears almost inevitable that curiosity about the performative brain is liable to lead one to a nonmodern conception of the self, different from and more expansive than the modern. We might see yogic feats, for instance, as another example of ontological theater—pointing to an understanding of the brain and self as endlessly explorable, exceedingly complex systems and, at the same time, pointing to the sort of performances one might attempt given such a conception of the brain (but that one might never imagine in relation to the representational brain). We can also note that a certain nonmodern spirituality begins to surface here in association with the nonmodern self—a species of earthy spirituality that goes with embodied yogic performances, say, rather than the purified spirituality and the "crossed-out God" of Christianity that Latour (1993) characterizes as part of the "modern settlement." This form of spirituality will also reappear in the following chapters.[60]

4. Walter associated particular altered states and strange performances with specific *technologies of the self*, as I will call them, following Michel Foucault (1988). We have already encountered several examples of these—the specific material setups that Walter used to drive his robots mad (contradictory conditioning across different sensory channels), his techniques for restoring them to sanity (leaving them alone for extended periods, switching them on and off, disconnecting circuits), and their presumptive equivalents in the human world—and we can examine more of them as we go on. But now I should note that the technologies that will concern us are not substantively the same ones that interested Foucault. Foucault's concern was with the histories of specific techniques of *self-control*, aimed at forming specific variants of the autonomous freestanding individual, of the modern self as I just de-

fined it. The technologies that we need to explore, in contrast, undermine the modern duality of people and things by foregrounding couplings of self and others—another instance of ontological theater. On Walter's account, inner states of the brain and, by extension, the self were not to be ascribed to pure inner causes, but to intersections with the nonself, to external configurations like the cross-conditioning setups associated with madness. To emphasize this, I will refer to such techniques as technologies of the nonmodern self. From this angle, too, we see how a conception of the performative brain can lead to a nonmodern decentering of the self—a theme that will come back repeatedly in the following chapters.[61]

5. *The Living Brain* did not simply offer a catalog of altered states and technologies of the self. In more or less detail, Walter also sought to sketch out the mechanisms that connected them. His most detailed accounts were of the go of madness, along the lines sketched out above, and epilepsy (see below). But he also argued that CORA could be taken to illuminate conditioning mechanisms by which Eastern yogis acquired their odd powers over otherwise autonomous bodily functions; that nirvana—"the peace that passeth understanding, the derided 'happiness that lies within' "—could be understood as "the experience of homeostasis" (1953, 39; more on homeostasis in the next chapter); and so on. Again, cybernetics as brain science appears here as the other side of a performative brain that inhabits spaces of ecstasy and madness as well as the everyday world.

6. If Walter's list of strange performances and altered states seems odd and wild, it is because the marginalization of many of its entries has been central to the constitution of modernity and the conception of the dualist, freestanding modern self. The East, with its yogis and fakirs, is the other to modern science, the modern self, and the modern West. Dreams and visions are, shall we say, at the edges of modern consciousness.[62] This is the nonmodernity of cybernetics, once more. But . . .

7. There was a time when the list appeared less wild: the sixties. Madness and ecstasy, the East and Eastern spirituality, strange performances, altered states, explorations of consciousness—these were some trademark preoccupations and practices of the sixties counterculture. We can examine below a couple of direct crossovers from Walter and *The Living Brain* to the sixties, but to make the connection another way, we could think of the work of a canonical sixties author, Aldous Huxley. Huxley's visionary account of his first experience of mescaline in *The Doors of Perception* (1954) became required reading in the sixties, along with its sequel, *Heaven and Hell* (1956; published as a single volume in 1963). And what interests me here is that *Heaven and*

*Hell* is isomorphous with *The Living Brain* in the respects now under discussion. It, too, offers a long catalog of altered states running from madness to ecstasy and enlightenment, coupled both with an exegesis in terms of Eastern spirituality (specifically Buddhism) and with scientific explanations of the origins of such states. This isomorphism between Walter and Huxley points, I think, to a commonality between cybernetics and the sixties, precisely in a shared interest in the performative brain, a curiosity about what it can do, and, in general, a fascination with nonmodern selves.[63] We can return to the sixties in a moment, but first we need to examine another aspect of Walter's technical EEG research.

## Flicker

"Flicker" is a long-standing term of art in experimental psychology, referring to visual effects induced by flickering lights (Geiger 2003, 12–15). A spinning top with black and white bands induces perceptions of color, for example. Walter became interested in flicker and incorporated it into his EEG research in 1945, when he came across a new piece of technology that had become available during the war, an electronic stroboscope. Staring at the machine through closed eyelids, he reported, "I remember vividly the peculiar sensation of light-headedness I felt at flash rates between 6 and 20 [per second] and I thought at once 'Is this how one feels in a petit mal attack?—Of course this could be how one can *induce* a petit mal attack" (Walter 1966, 8).[64] And, indeed, when he experimented with a strobe on an epileptic patient, "within a few seconds a typical wave-&-spike discharge developed as predicted." The quotation continues: "This was enormously exciting because I think it was the first time that a little theory [in EEG research] based on empirical observation had actually been confirmed by experiment. This meant that there might be some hope of reinstating the EEG as a scientific rather than merely utilitarian pursuit. . . . This was one of the critical turning points in our history." The scientific import of flicker in EEG research was thus that it offered a new purchase on the performative brain, and a new neurophysiological and clinical research program opened up here, pursuing the effects of "photic driving" at different frequencies with different subjects. Walter and his colleagues at the Burden, including his wife, Vivian Dovey, experimented on nonepileptic as well as epileptic subjects and found that (Walter 1953, 97) "epileptic seizures are not the exclusive property of the clinically epileptic brain. . . . We examined several hundred 'control' subjects—schoolchildren, students, various groups of adults. In three or four percent of these, carefully adjusted flicker evoked responses indistinguishable from those previously regarded as 'diagnostic' of clinical epilepsy. When these responses appeared, the subjects would exclaim at the 'strange feelings,' the faintness or swimming in the head; some became unresponsive or unconscious for a few moments; in some the limbs jerked in rhythm with the flashes of light." It turned out the optimal flicker frequency for the induction of such effects was often hard to find, and at the Burden Harold "Shippy" Shipton built a feedback apparatus (Walter 1953, 99) "in the form of a trigger circuit, the flash being fired by the brain rhythms themselves. . . . With this instrument the effects of flicker are even more drastic than when the stimulus rate is fixed by the operator. The most significant observation is that in more than 50 per cent of young normal adult subjects, the first exposure to feedback flicker evokes transient paroxysmal discharges of the type seen so often in epileptics" (fig. 3.12).

To follow the details of this research would take us too far afield, so let me make a few comments on it before going back to the sixties.[65] First, Walter's work here exemplifies my earlier remarks about the possibility of being curious about the performative brain. If our capacity for cognitive tasks is immediately before us—I already know that I can do crosswords and sudoku puzzles—the epileptic response to flicker was, in contrast, a surprise, a discovery about what the performative brain can do. Second, this research points again to the psychiatric matrix in which Walter's cybernetics developed. Third, experiments aimed at inducing quasi-epilieptic fits in schoolchildren should only make us grateful for the controls on human-subjects experimentation that have since been introduced.[66] Fourth, flicker is a nice exemplification of my notion of a technology of the self, a material technology for the production of altered states. If you want a paradigmatic example of a technology of the nonmodern self, think of flicker. Fifth and finally, Shippy's feedback circuit deserves some reflection. In the basic flicker setup the brain was pinned down in a linear relation to the technology. The technology did something—flickered—and the brain did something in response—exhibited epileptic symptoms. This counts as a piece of ontological theater inasmuch as it thematizes the performative brain, the brain that acts rather than thinks. But it does not thematize the adaptive brain, the key referent of cybernetics per se: there is no reciprocal back-and-forth between the brain and its environment. Feedback flicker, in contrast, staged a vision of the adaptive brain, albeit in a rather horrifying way. The strobe stimulated the brain, the emergent brainwaves stimulated the feedback circuit, the circuit controlled the strobe, which stimulated the brain, and so on around the loop. We could say that the brain explored the performative potential of the material technology

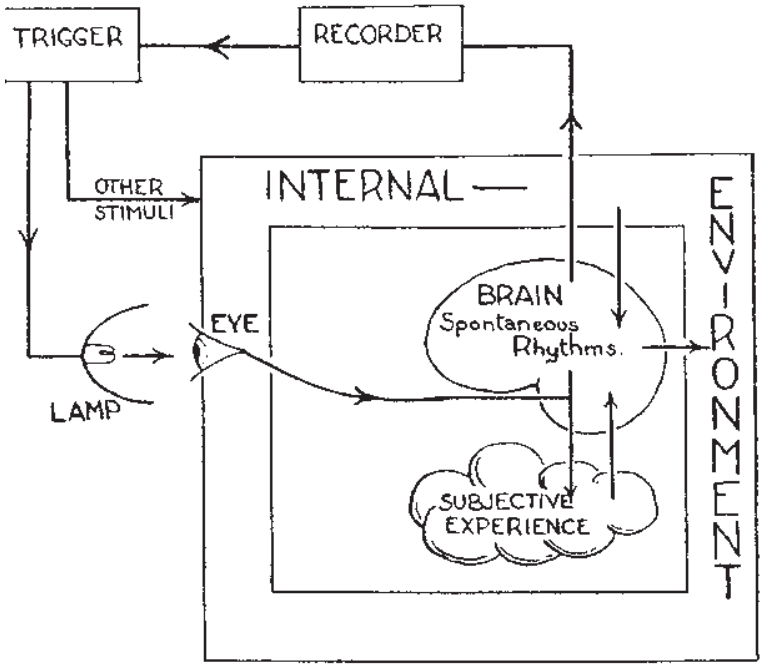


**Figure 3.12.** Feedback-controlled flicker. Source: V. J. Walter and W. G. Walter, "The Central Effects of Rhythmic Sensory Stimulation," *Electroencephalography and Clinical Neurophysiology*, 1 (1949), 57–86, p. 84, fig. 18.

(in an entirely nonvoluntary, nonmodern fashion), while the technology explored the space of brain performance. I suggested earlier that the tortoise was unsatisfactory as ontological theater inasmuch as its world was largely passive and unresponsive, and I therefore want to note that feedback flicker offers us a more symmetric ontological spectacle, lively on both sides—a dance of agency between the human and the nonhuman. What acted in these experiments was genuinely a cyborg, a lively, decentered combination of human and machine.

We can come back to this below in a discussion of the history of biofeedback, and at a more general level in the following chapter on Ashby's cybernetics.

## Flicker and the Sixties

Walter and his colleagues experimented with strobes not only on laboratory subjects but also on themselves, and (Walter 1953, 101) "we all noticed a peculiar effect . . . a vivid illusion of moving patterns whenever one closed one's eyes and allowed the flicker to shine through the eyelids. The illusion . . . takes a variety of forms. Usually it is a sort of pulsating check or mosaic, often in bright colours. At certain frequencies—around 10 per second—some subjects see whirling spirals, whirlpools, explosions, Catherine wheels." Again we can understand these observations as a discovery about the performative brain, continuing a longer tradition of research into such effects in experimental psychology. Walter (1953, 107–13) in fact conjectured that the moving patterns were related to the scanning function of the alpha waves (as materialized in the tortoise): since there is no motion in the strobe light, perhaps the pulsation and whirling in the visual effects comes from the scanning mechanism itself, somehow traveling around the brain. But the language itself is interesting. This passage continues: "A vivid description is given by Margiad Evans in 'A Ray of Darkness': 'I lay there holding the green thumbless hand of the leaf. . . . Lights like comets dangled before me, slow at first and then gaining a fury of speed and change, whirling colour into colour, angle into angle. They were all pure unearthly colours, mental colours, not deep visual ones. There was no glow in them but only activity and revolution.' "[67] What should we make of a passage like that? The word that came to my mind when I first read it was "psychedelic." And I immediately thought of some key texts that were required reading in the sixties, especially Huxley's *The Doors of Perception*. Then I was fortunate enough to obtain a copy of a wonderful recent book by John Geiger called *Chapel of Extreme Experience* (2003).[68] Geiger traces out beautifully how Walter's work on flicker entered into sixties culture. I have little substance to add to Geiger's account, but I want to review his story, since it adds importantly to our topic.

We need to think of three lines of development. First and most conventionally, Walter's observations on flicker fed into a distinctive branch of work in experimental psychology aimed at elucidating its properties, exploring, for example, the kinds of images and visions that flicker produced, and into philosophical reflections on the same. Interestingly, these explorations of flicker were typically entwined with explorations of the effects of psychoactive drugs such as mescaline and LSD. It turned out that the hallucinogenic effects of these drugs are intensified by flicker and vice versa. These fascinating branches of psychological and philosophical research on the performative brain flourished in the 1950s and 1960s but seem since to have been largely forgotten—no doubt due to the criminalization of the drugs.[69] Of more direct interest to the student of popular culture is that Aldous Huxley indeed appears in this story. His 1956 book *Heaven and Hell* indeed includes flicker, experienced on its own or in conjunction with LSD, in its catalog of technologies of the nonmodern self (A. Huxley 1956, 113–14).

At the wildest end of the spectrum, in the late 1950s flicker came to the attention of the group of writers and artists that centered on William Burroughs and Allen Ginsberg, often to be found in Tangiers, where Paul Bowles was a key figure, or staying at the Beat Hotel, 9 rue Git le Coeur in Paris. As I mentioned earlier, the Beats' connection to Walter was textual, chancy, and undisciplined, going via *The Living Brain*. Burroughs read it and was fascinated to find that "consciousness expanding experience has been produced by flicker."[70] For the Beats also, flicker and drugs ran together. In 1959, when Ginsberg took acid for the first time at the Mental Research Institute in Palo Alto, it was in the framework of a typical Grey Walter setup: "Burroughs suggested he did so in concert with a stroboscope. The researchers . . . connected the flicker machine to an EEG, so that Ginsberg's own alpha waves would trigger the flashes." I mentioned earlier the strikingly cyborg aspect of such a configuration, and interestingly, Ginsberg experienced it as such (quoted by Geiger 2003, 47): "It was like watching my own inner organism. There was no distinction between inner and outer. Suddenly I got this uncanny sense that I was really no different than all of this mechanical machinery all around me. I began thinking that if I let this go on, something awful would happen. I would be absorbed into the electrical grid of the entire nation. Then I began feeling a slight crackling along the hemispheres of my skull. I felt my soul being sucked out through the light into the wall socket." Burroughs also gave a copy of *The Living Brain* to another of the Beats, the writer and artist Brion Gysin, who recognized in Walter's description of flicker a quasi-mystical experience he had once had on a bus, induced by sunlight flashing through the trees. Gysin in turn discussed flicker with another member of Burroughs's circle, Ian Sommerville, a mathematics student at Cambridge, and in early 1960 Sommerville built the first do-it-yourself flicker machine—a cylinder with slots around its circumference, standing on a 78 rpm turntable with a 100 watt lightbulb in the middle (fig. 3.13). It turned out that fancy and expensive stroboscopes were not necessary to induce the sought-after effects—this cheap and simple Dream Machine (or Dreamachine), as Gysin called it, was quite enough (Geiger 2003, 48–49).[71]

From here one can trace the cultural trajectory of flicker in several directions. Burroughs both referred to flicker in his writing and built it into his prose style in his "cut-up" experiments (Geiger 2003, 52–53).[72] Gysin and Sommerville published essays on and construction details for their Dream Machine in the journal *Olympia* in February 1962 (Geiger 2003, 62). Timothy Leary, ex-Harvard psychologist and acid guru, was one of the Beats' suppliers of drugs and learned from them of flicker, which he began to discuss, along

**Figure 3.13.** Brion Gysin and the Dream Machine. Source: Geiger 2003, 50. (Copyright © John Geiger from *Chapel of Extreme Experience: A Short History of Stroboscopic Light and the Dream Machine*. Reprinted by permission of Counterpoint. Photograph copyright © 2000 by Harold Chapman.)

with Grey Walter, in his own writings.[73] Gysin displayed Dream Machines as art objects in a series of exhibitions and argued that they marked a break into a new kind of art that should displace all that had gone before: "What is art? What is color? What is vision? These old questions demand new answers when, in the light of the Dream Machine, one sees all ancient and modern abstract art with eyes closed" (Gysin quoted by Geiger 2003, 62).[74]

Gysin was also taken with the idea of the Dream Machine as a drug-free point of access to transcendental states, and had plans to develop it as a commercial proposition, something to replace the television in people's living rooms, but all his efforts in that direction failed (Geiger 2003, 66 & passim). And in the end, the flicker technology that entered popular culture was not the cheap Dream Machine but the hi-tech strobe light.[75] As Geiger puts it (2003, 82–83): "By 1968 . . . stroboscopic lights were flashing everywhere. They . . . had been taken up by the drug culture. Ken Kesey featured strobe lights in his 'Acid Tests'—parties where he served guests LSD-laced Kool-Aid to the music of the Grateful Dead. . . . Tom Wolfe wrote in *The Electric Kool-Aid Acid Test*: 'The strobe has certain magical properties in the world of acid heads. At certain speeds stroboscopic lights are so synched in with the pattern of brain waves that they can throw epileptics into a seizure. Heads discovered that strobes could project them into many of the sensations of an LSD experience without taking LSD.'" Flicker, then, was an axis along which Walter's cybernetics played into the distinctive culture of the high 1960s.[76] And Walter himself was happy to claim a share of the credit. In a 1968 talk he remarked, "Illusory experiences produced by flashing lights . . . nowadays are used as a standard method of stimulation in some subcultures. I should be paid a royalty because I was the first to describe these effects" (quoted by Geiger 2003, 83).

This is as far as I can take the story of flicker and the sixties, and the key points to note are, first, that this cultural crossover from Walter's cybernetics to the drug culture and the Beats indeed took place and, second, that the crossover is easy to understand ontologically.[77] In different ways, the sixties and cybernetics shared an interest in the performative brain, with technologies of the decentered self as a point of exchange. The sixties were the heroic era of explorations of consciousness, and flicker joined a whole armory of such sixties technologies: psychedelic drugs, as already mentioned, meditation, sensory deprivation tanks, as pioneered by John Lilly (1972), and even trepanning.[78] In the next section we can take a quick look at yet another such technology: biofeedback. For now, three remarks are in order.

First, just as I conceive of cybernetics as ontology in action, playing out the sort of inquiries that one might associate with a performative understanding of the brain, one can equally see the sixties as a form of ontological theater staging the same concerns, not in brain science but in unconventional forms of daily life.

Second, I want to emphasize the sheer oddity of Gysin's Dream Machines, their discordant relation to everyday objects and the traditions in which they are embedded. In the field of art, it is probably sufficient to quote Gysin himself, who justifiably described the Dream Machine as "the first artwork in history made to be viewed with closed eyes" (Geiger 2003, 54). As a commercial proposition, the Dream Machine was just as problematic. In December 1964, Gysin showed a version to representatives from Columbia Records, Pocketbooks, and Random House, and "all present were soon trying to understand what they had and how to market it. Was it something that could be sold in book form with cut-outs, or was it something that could be sold with LPs? Columbia Records' advertising director Alvin Goldstein suggested the Dream Machine would make a great lamp. Someone said they could be used in window displays" (Geiger 2003, 69). In its unclassifiability, the Dream machine exemplifies in the realm of material technology my thesis that ontology makes a difference.

Finally, I should return to the question of the social transmission of cybernetics. Just as we saw earlier in the history of robotics, flicker's crossover from cybernetics to the Beats took place via a popular book, *The Living Brain*, and thus outside any disciplined form of social transmission. The focus of Walter's book is resolutely on the human brain; it is not a book about art or living-room furniture. But Gysin read "half a sentence," and "I said, 'Oh, wow, that's it!' " (quoted in Geiger 2003, 49). Although not evident in the story of the Walter-Brooks connection in robotics, a corollary of the chancy mode in which cybernetics was transmitted was, as I said earlier, the opportunity for wild mutation—the transmutation of brain science into art objects and psychedelic replacements for the TV.

## Biofeedback and New Music

THE SOUNDS THAT ARE "ALLOWED TO BE THEMSELVES" IN LUCIER'S WORK HAVE ALWAYS HAD A MYSTERIOUSLY "EXPRESSIVE" QUALITY. SOMETIMES I THINK IT IS INARTICULATE NATURE SPEAKING TO US HERE.

**JAMES TENNEY**, "THE ELOQUENT VOICE OF NATURE" (1995)

"Biofeedback" refers to another set of technologies of the nonmodern self, techniques for reading out "autonomous" bodily parameters such as brain rhythms and displaying them to subjects, thus making them potentially subject to purposeful intervention. Shipton's flicker-feedback circuit might be described as such a device, except that there was no choice in the matter: the circuit locked onto the subject's brainwaves and fed them back as flicker whether the subject liked it or not. Walter describes a more voluntary biofeedback arrangement in *The Living Brain* (1953, 240). The onset of sleep and anger is marked by an increase in low-frequency theta rhythms in the brain, and Walter imagines an EEG setup in which this increase flashes a light or rings a bell: "Worn by hard-driving motorists, theta warning-sets would probably save more lives than do motor horns, and they might assist self-knowledge and self-control."[79] In the 1960s, biofeedback came to refer to a species of self-training, in which subjects learned to control aspects of their EEG spectrum (without ever being able to articulate how they did it).[80]

We could follow the history of biofeedback in several directions. Going back to our earlier clinical concerns, Jim Robbins (2000) offers a popular account of the history of biofeedback in psychiatry and of present-day uses in the treatment of a whole range of disorders including epilepsy, learning disabilities, autism, and PTSD.[81] He notes, however, that biofeedback was also taken up by the sixties counterculture in pursuit of alpha-wave-dominated states that had become identified with transcendental experiences (fig. 3.14). The first meeting of biofeedback professionals took place at Snowmass, Colorado, in 1968, and the attendees were "a mixture of uptight scientific types . . . and people barefooted, wearing white robes, with long hair. It attracted the

**Figure 3.14.** EEG biofeedback. The photograph ran with an article entitled “What a Sexy Brainwave” and had a caption reading, “Georgina Boyle calls up those no-worry waves.” Source: *Sunday Mirror* (London), 12 December 1971, 22.

heads to a tremendous extent” (Robbins 2000, 65, quoting Joe Kamiya, a pioneer in the scientific exploration of biofeedback). David Rorvik (1970) elaborates on this in much the same terms as were applied to flicker: “Now, with the dawning of the cybernetic seventies, it is not too surprising that LSD and the other hallucinogens of the sixties are about to be eclipsed, in a sense, by an electronic successor: BFT. Bio-Feedback Training, or ‘electronic yoga’ as it has been called, puts you in touch with inner space, just like LSD but, unlike acid, leaves you in full control of your senses. And, unlike meditation, it doesn’t take years of sitting on mountaintops to master. . . . There are those who believe that biofeedback training may not only illuminate the myriad workings of the mind but may even fling open the doors to entirely new kinds of experience, extending the inner dimensions of the emergent cybernetic man” (1970, 175–76).

Here, though, I want to explore another intersection of cybernetics and the arts. If flicker was a distinctive and paradoxical contribution to the visual arts, biofeedback in turn fed into the New Music of the 1960s, usually associated with names like John Cage and David Tudor.[82] The idea was simple enough. In a basic brainwave biofeedback setup, a light comes on when the subject's alpha output, say, exceeds some level, and by focusing on keeping the light lit, subjects somehow learn to boost their alpha level at will. To go from this setup to music, all that was required was to substitute sound for the visual element of the feedback circuit. The difficulty was, in the first instance, that alpha frequencies are below the range of hearing, and one solution, used from time to time, was to record brain activity to tape and then play it back in speeded-up form, thus making it audible. The drawback to such a solution was that it blocked the possibility of any real-time feedback coupling between performer and performance, and the first recognized EEG music event followed a different route. First performed live in 1965, Alvin Lucier's *Music for Solo Performer* fed the EEG readout directly into loudpeakers whenever the alpha rhythms were above the threshold, generating an audible output by putting the speakers next to or in contact with "gongs, timpani, bass drums, anything that loudspeakers could vibrate sympathetically" (Lucier 1995, 50)—even a metal dustbin (fig. 3.15).[83]

Several points are worth noting about this style of alpha music. Most evidently, like feedback-controlled flicker, it brings us face to face with a form of decentering of the self into a technosocial apparatus. Any given performance of *Music for Solo Performer* was not the work of a solo performer: it was the work of a human plus EEG electrodes, amplifiers and signal analyzers, switches, loudspeakers, and sound generating devices of all sorts. Second, even with extensive biofeedback training, in such a setup the performer does not exercise absolute control over the performance. From one angle, the sounds themselves are what enable the performer to tune into the generation of alpha waves—that is the principle of biofeedback. Nevertheless, "although theoretically it [the alpha rhythm] is a continual pattern of ten hertz, it never comes out that way because it stops when your eyelids flutter or you visualise a little and it tends to drift down a bit if you get bored or sleepy" (Lucier 1995, 58). One has the sense, then, of a reciprocal and open-ended interplay between the performer and the performance, with each both stimulating and interfering with the other—a kind of reciprocal steersmanship, in the sense discussed in chapter 2. We can go into this further in chapter 6, on Brian Eno's music, and chapter 7, on Pask's cybernetic aesthetics, but I want to suggest here that biofeedback music can stand as another and very nice example of

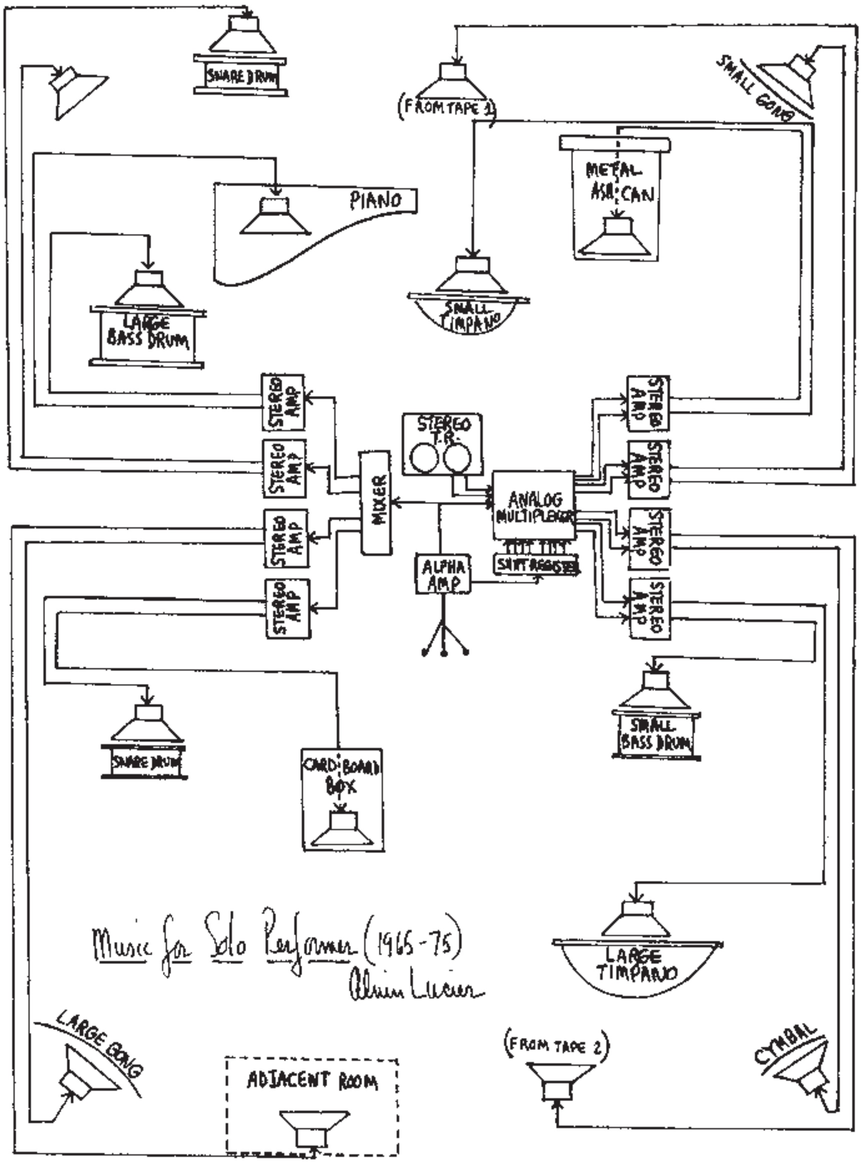


**Figure 3.15.** Music for solo performer. Source: A. Lucier, *Reflections: Interviews, Scores, Writings*, edited by G. Gronemeyer and R. Oehlschlägel (Köln: MusikTexte, 1995), 54.

ontological theater—of an open-ended and performative interplay between agents that are not capable of dominating each other. Second, I do not need to labor the point that here again ontology makes a difference—*Music for Solo Performer* is self-evidently different from mainstream notions of music. As James Tenney (1995, 12) put it, "Before [the first performance of *Music for a Solo Performer*] no one would have thought it necessary to define the word 'music' in a way which allowed for such a manifestation; afterwards some definition could not be avoided." Third, we can note that we are once more back on the terrain of altered states (and, literally, strange performances!). Lucier speaks of a "perfectly meditative alpha state" (1995, 56), and, in this sense, the decentered quality of the musical performance hung together with a decentered, nonmodern subject position of the performer. Fourth, I want to comment on what I think of as the *hylozoism* of this sort of music, but to get clear on that it helps to refer to the work of another pioneer in this field, Richard Teitelbaum.

Teitelbaum was yet another person who had a transformative encounter with Walter's writings. In 1966, "by chance, I found a copy of W. Grey Walter's pioneering work *The Living Brain* in Rome. Studying it thoroughly, I was particularly interested in the sections on flicker and alpha feedback, and by descriptions of the hallucinatory experiences reported by some subjects" (Teitelbaum 1974, 55). Having learned of Lucier's work, Teitelbaum hit upon the idea of using EEG readouts to control the electronic synthesizers then being developed in the United States by Robert Moog (on which see Pinch and Trocco 2002), which led to the first performance of a work called *Spacecraft* by the Musica Elettronica Viva Group on a tour of Europe in autumn 1967 (Teitelbaum 1974, 57). On the experience of performing in *Spacecraft*, Teitelbaum recalled that (59)

> the unusual sensations of body transcendence and ego-loss that occurred in this music—and in related biofeedback experiences—seemed aptly described . . . in the Jewish mystical texts of the Kabbalah: in the state of ecstacy a man "suddenly sees the shape of his self before him talking to him and he forgets his self and it is disengaged from him and he sees the shape of his self before him talking to him and predicting the future." With five musicians simultaneously engaged in the same activities—electronically mixing, inter-modulating with each other and issuing from the same loudspeakers—a process of non-ordinary communication developed, guiding individual into collective consciousness, merging the many into one.

By the slippery word "hylozoism" I want to refer to a spiritually charged awe at the performative powers of nature that seems to inhabit this quotation: the idea evident in Teitelbaum's and Lucier's work (and in the New Music of the sixties more generally) that, so to speak, it's all there in nature already, that the classically modern detour through human creativity and design is just that, a detour that we could dispense with in favor of making nature itself—here the alpha rhythms of the brain—audible (or visible).[84] Let me just note for the moment that this idea goes very well with the cybernetic ontology of performative interaction. Again we can understand Teitelbaum's work as cybernetic ontological theater—an approach to music that at once conjures

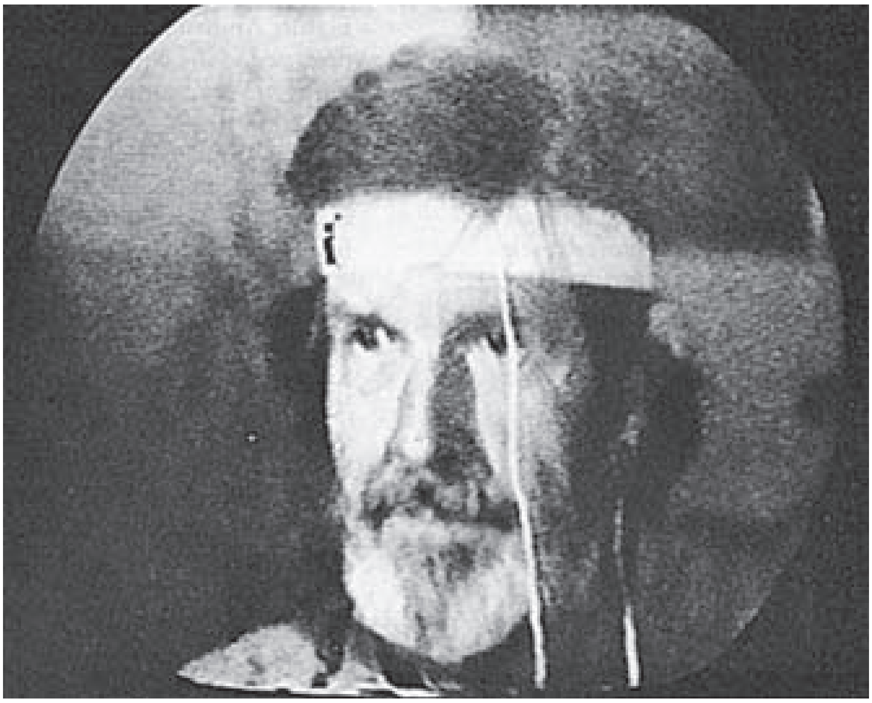

**Figure 3.16.** Still from a video of John Cage during alpha feedback. Source: Teitelbaum 1974, 68.

up the overall ontological vision and exemplifies how that vision might be distinctively instantiated and developed in real-world practice. The topic of hylozoism recurs in the following chapters in various guises, at greatest length in chapter 6, on Stafford Beer. We can pick up the related question of a distinctively cybernetic stance on design in the next chapter, on Ross Ashby.[85]

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This is the end of our first close encounter with British cybernetics. In terms of material technologies, I described Walter's tortoises as specimens of ontological theater, contemplation of which helps one to grasp the performative and adaptive ontology of cybernetics, and as ontology in action, an instance of how one might proceed in brain science (and other fields) if one takes that ontology seriously. The contrast between Walter's robotics and that associated with AI illustrates my idea that ontology makes a difference—that very different practices can hang together with different understandings of what the world is like. From the tortoises we moved on to CORA, which staged for us a performative epistemology, directly geared into the performative ontology staged by the naked tortoise, and which also made the connection between Walter's cybernetics and the psychiatric milieu from which it emerged. Finally, the discussion of flicker and biofeedback touched on other lines of inquiry into the performative brain and crossovers between cybernetics and the psychedelic sixties, with the sixties, too, graspable as ontological theater and ontology in action.

At the same time, the history of Walter's cybernetics begins an exemplification of what I called the protean quality of cybernetics, with the tortoises spanning the worlds of brain science, psychiatry, robotics, and entertainment—and we can now add to this list the Dream Machine and biofeedback setups as pivots to the wider culture and the arts. This multiplicity can be associated with the lack of any stable institutional basis for cybernetics, with first the Ratio Club and then the Namur conferences as key nexuses in Britain and Europe; and with the disorganized, undisciplined mode of cybernetic transmission and the possibilities for mutation that went with that.

Next we come to Walter's contemporary in the first generation of British cyberneticians, Ross Ashby. As we shall see, Ashby's cybernetics grew around a notion of adaptation that was different from and richer than Walter's, and it was, in fact, Ashby's vision of adaptation (shared by Gregory Bateson) that informed the work of the second generation, Stafford Beer and Gordon Pask.