Toys are Us
Models and Metaphors in Brain Research

Cornelius Borck

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“A model … is something you hold in your head rather than in your hands.”

(Ian Hacking, 1983, p. 216)

Regardless of its seemingly abstract philosophical nature, historically the relation of mind and body has found a surprising variety of forms in the changing “mirror of machines” (Meyer-Drawe, 1996)—perhaps because the “invention” of abstract theorizing and knowledge coincided with the construction of tools and machines. Friedrich Nietzsche brought this articulation of knowledge and machines famously to the fore in his Birth of Tragedy, when he lamented that with the invention of machines, the artful wisdom of the mythos, and the metaphysical consolation it offered, was lost and replaced with the “deus ex machina, namely the god of the machines and crucibles, … the belief in knowledge and a life led by science” (Nietzsche, 1872, § 17). He dated this shift to the transformation of tragedy from its early to the classical form in Greek antiquity; a period which also saw the rise of science and philosophy. Nietzsche wrote his essay during the Franco–Prussian war, a fact that may have influenced his analysis, because this was a time when modern science and the process of industrialization changed the world in hitherto unanticipated ways (Nietzsche reflected upon this in an introduction of the book which he added later).

At the same time, two young physician-scientists once again changed the relation between mind and brain, when they experimented with the application of electric currents to the cortex and observed its excitability. In 1870, Gustav Fritsch and Eduard Hitzig reported on their experiments with cerebrally induced contractions in dogs (Fritsch & Hitzig, 1870; Hagner, 1993). The electric excitability of the brain had been demonstrated almost a hundred years after Luigi Galvani had discovered animal electricity, even though his discovery of it in 1780 had sparked an intense debate on—and much research into—the nature of the nervous principle (Brazier, 1961). Applying electrical stimuli to different sites of the exposed surface of
the cortex, Fritsch and Hitzig observed that the stimulation of areas in the frontal half of the cerebral hemispheres resulted in muscular contractions in the opposite side of the body. This single publication ended a long and puzzling debate about psychophysiological principles by demonstrating the brain to operate like an electrical apparatus (Young, 1970, pp. 224–240).

Their findings were confirmed and further developed by the British physiologist David Ferrier, when he established, in experiments with monkeys, the principle of cerebral localization—for example the functional specialization and strict topographical organization of the cortex (Ferrier, 1873, 1876). Seeing one of Ferrier’s experimental monkeys with a paralyzed limb, Martin Charcot is reported to have remarked “C’est un malade!” (quoted from Viets, 1938, p. 482). Ferrier’s experiments were, indeed, quickly transferred to human beings (Zago, Ferrucci, Fregni, & Priori, 2008). In effect, the replication of the stimulation experiment in humans resulted in a second metonymic replacement, namely the transformation of the human body into an electromechanical device, executing automatic movements of specific definition due to the precise electrical stimulation of the centers of control. This transformation was to happen a generation later, when neurosurgeons started to introduce cerebral stimulation into the operating theater.

Starting with a closer look at Wilder Penfield’s exploration of the functional topography of the cerebral cortex and his use of instruments as technical (material) as well as heuristic (metaphorical) tools, this chapter compares and contrasts different strands in the employment of machines as cognitive tools in the neurosciences. Over the course of more than 200 years, a changing series of models and metaphors was brought forward and new research methods were developed to conceive of the brain; this created a dynamic exchange between models, metaphors, and research strategies for accommodating and generating new masses of data. Focussing on twentieth-century research, this chapter’s objective is not to examine the neurosciences in their entirety or to trace every single analogy or metaphor, but rather to analyze the cognitive significance of this strategy and the epistemic implications of different approaches.

For a long time tools and instruments were simply not sophisticated or complex enough for use as compelling correlates; yet their very limitations could be employed for demonstrating the brain’s functional superiority. Only with the arrival of automata, in particular the computer as a logical apparatus of calculation, did the relation between brain and machine change; what had once been a comparison across a generally shared understanding of differences turned into rivalry and competition. Now the metaphorical explanation of brains as machines acquired a material, concrete reality and the philosophical program of materialism turned into reductionism. As if to testify to its allegedly anti-human nature, humans soon lost the competition with machines in calculation capability and other supposed indicators of human intelligence. At this point, towards the end of the twentieth century, the emphasis shifted to other aspects of human nature that apparently escaped comparison with machines, such as empathy and the social brain. At the same time however, the arrival of functional imaging promised to discard functional comparisons in general and to conflate the technological visualization with a neurophysiological substrate. Machines may always have lacked something essentially human but the mobilization of machine metaphors
operated on the crucial basis of a differentiality between men and machines. In the interplay of shortcomings, limitations, and transgressions, machine metaphors opened the space for critical humanism in brain theory that is overlooked or extinguished in the current identification of substrate and significance in functional imaging.

The Tape Recorder and the Electrode

Realizing that, because of the brain tissue’s insensitivity to pain, brain surgery could be performed with local anesthesia, Fedor Krause in Berlin and Otfrid Foerster in Breslau pioneered a procedure which was as much a therapeutic intervention as a neurophysiological experiment (Foerster, 1923; Krause, 1911). Later, the neurosurgeon Wilder Penfield perfected this technique at the Montreal Neurological Institute by morphing Ferrier’s chart to the famous homunculus of the cortical representation of bodily functions (Penfield & Rasmussen, 1950). Immediately before moving to Canada, Penfield spent six months with Foerster in Breslau where he trained to explore by electrical stimulation the brain of the awake patient during surgery. The issue was to determine the functional specificity of particular regions of the brain in order to save them during surgery. Penfield would open a patient’s skull, expose the surface of the brain, and map its functional topography by stepping down point by point with his stimulating electrode along the brain’s gyri, hereby eliciting the respective physiological responses. For this, not only had the operating theater been converted into a special electrophysiological laboratory, but both the operating team and the patient embarked together on an expedition into new territory. The tip of the stimulating electrode acted as voyager into the lands usually hidden not only inside the skull but deep in the vaults of the psyche. In Penfield’s hands came the surprise, when the electrode entered Memoria, the lands of yesterday; Penfield perfected neurostimulation to a form of time travel.

Besides eliciting various forms of motor response, such as the movement of a finger, arm, or toe that confirmed the (by then) well known topography of the motor cortex, Penfield’s electrode triggered quite different reactions when less well characterized areas of the brain were investigated, in particular structures further down the temporal cortex. Here, Penfield’s electrical explorations resulted in the patient undergoing experiences of a forced déjà vu; again and again, the stimulating electrode acted as a memory activator bringing back a distinct “single recollection,” not “a mixture of memories or a generalization” (Penfield, 1952, p. 180). But in contrast to the sensory or the motor cortex, there was no apparent topographical correspondence between the position of the electrode and the experiential content or the emotional quality of a memory re-actualized and hence Penfield could not control the experience with his electrode. Instead, the recollections evoked by the electrical activation of the temporal cortex retained the rich details of the original experience—and often even more strongly compared to the habitual act of remembering. The memories forced into the patient’s consciousness were experienced not only as present but often as “more real” than regular memories, and the patients retained some sense of a mixed reality, “somehow doubly conscious of two simultaneous situations” (Penfield, 1952, p. 184). Apart from these generalizable characteristics, it was entirely left to the
positioning of the electrode whether the stimulation elicited the permanent boredom of an office life or a happy family reunion across oceans.

For Penfield, the accuracy and comprehensiveness of the memory apparatus he had accessed by means of the stimulating electrode were most remarkable. The individual’s ability to actively recall particular episodes may have been observed to differ from patient to patient, but deep down in their brains every detail of their lives was being recorded with the precision of a machine. The automatic operations of this memory system could best be described as the action of a kind of tape recorder, continuously recording the events of a life, from birth to death. However, this was a very special type of recorder that did not register the events as they occurred in the outside world, but from the internal perspective of the subject—as Penfield aptly described by differentiating the metaphor in terms of its technological validity vis-à-vis the experiential quality:

The subject feels again the emotion which the situation originally produced in him, and he is aware of the same interpretation, true or false, which he himself gave to the experience in the first place. Thus, evoked recollection is not the exact photographic or phonographic reproduction of past scenes and events.

(Penfield, 1952, p. 183)

The experiments exemplified William James’ notion of a continuous “stream of consciousness” (James, 1892, chapter IX), though this had also once just been a metaphor. Now, experimental research had proven that somewhere inside the head there was a material structure which acted like a storage system and automatically preserved impressions from every moment of a life; though not the impressions in terms of the way they reached the body and stimulated the sensory organs, but in their perceived, emotionally charged and evaluated form. Technological advances now permitted access to this memory processing unit as a biological system, because it operated, in all likelihood, as an electrophysiological process and hence proved accessible by electrical stimulation.

The phonograph and the photograph were not quite the right models here, but they worked so well because they captured precisely what memory was not: an objective representation of the outside world. The memory system, by contrast, was an automatic registration unit for the subjective interpretation of sensory information. According to Penfield, the memory process did not work like a photograph or a phonograph, but it resembled some kind of psychic tape recorder. Penfield could thus embed his experiments in a set of material and metaphorical connections where technological models mediated perfectly between the two—the metaphor of the stream of consciousness and the electrophysiological process, or “the word and the world” (Morgan & Morrison, 1999).

Late in his life, after switching his career from the operating to the lecture theater, Penfield made a famous sketch connecting his experimental clinical observations with his general philosophical ideas, again by means of metaphorical connections. In this sketch, a chain of metaphors bridged the anatomy of the brain and its interior parts to “—M I N D—”, situated far away from the hippocampus and even outside the cortex (see Figure 5.1). The graphic symbol of the “key of access” connected the right and
left halves of the brain, and lines formed structural as well as logical bridges from the key symbol to the different sections of the hippocampi and from there through—or under—the cortex to the “stream of consciousness” that was the mind. In this sketch, the theory and the tool blended in new ways. Here, the stream of consciousness spanning life and death had become a spiral capturing on its strip of film, like a psychic video machine, all experiences awaiting recollection in the form of active retrieval or forced recollection by means of electric stimulation.

When the brain or some of its functions are being compared to technological inventions such as the camera, the phonograph, or the tape recorder, these models
stand in for specific functions attributed to the brain. Each of the models accentuates a particular, functional aspect of the brain. Yet the historical sequence of different technological models mobilized in order to grasp the brain’s functional capabilities also characterizes the investment in brain research for addressing the more fundamental questions about the nature of being human. For more than 200 years now, the brain has increasingly been mobilized as the central organ for addressing the condition humaine (Hagner, 1997). Investigating the arguments and ways in which particular models were adopted to explain the brain illuminates the complex history of this branch of research and elucidates how machines served for explanatory purposes inside and beyond the respective fields of technical application. In addition, it amounts to a rich and changing history of how scientists and the general public looked to the brain to answer vital humanist questions. Models in brain research typically mediated between questions of meaning, function, and significance on the one hand and the world of organic structures and mechanical functions on the other. Seen in this way, technological models are media in the multiple sense of the word, in that they transform and transmit information according to their technological specifications, and mediate between the world of biological function and the meaningful realm of day-to-day experience. They open a channel to the operations of the brain, which is structured by their technical functionality as well as by their cultural significance (Keller, 2000).

Compared to other branches of medicine or the life sciences, brain research has engaged in a particularly active dynamic with regard to metaphors and models; the result is an ongoing process of technological metamorphosis that shows little sign of abating (Draaisma, 2000). In contrast, for example, to the metaphor of the pump that was consolidated long ago in the physiology of the heart, the brain appears to be an unstable organ that has been compared to a wide and variable range of objects. The argument that is typically brought forward for this heterogeneity is the intrinsic complexity of the brain as a natural object whose very nature is apparently so much more than a single, simple device. Such a naturalistic argument is, however, more difficult than it may appear at first glance and should be treated with some caution by the historian—as becomes apparent when the brain is compared with organs such as the liver. Viewed at the level of molecular and biochemical processes, for example, there are probably very few organs surpassing the complexity of the liver’s synthesizing machinery. But in the Western tradition, the liver has lost much of its once valuable cultural significance; and hence its biological intricacy has been increased by biochemical investigations without much notice from circles outside the life sciences. Epistemologically speaking, the plain argument of anatomical design is not exclusively empirical and hence not trivial. The complexity so easily assumed to apply to the brain is very much an attributed quality, reflecting a cultural expectation and a desire to invest the brain with the elevated status of delivering compelling answers about human nature and intelligence.

Analyzing the contemporary media of the interwar period, Walter Benjamin famously spoke of the optical unconscious and declared film to be the central medium providing access to it “just like psychoanalysis did to the psychical” (Benjamin, 2008; Krauss, 1993). Benjamin’s idea of a materially grounded unconscious invites a fresh conceptualization not just of film but of media in general and a reading of their
currently electronic mode of operation, for example, as the cultural unconscious of modernity. Where has this process led to today and what will be the next step beyond the internet and augmented reality? Though Lenin did not yet know of the internet in his famous formula of communism as “Soviet power plus electrification,” he quite rightly pointed to the manifold effects and consequences of electrification beyond the narrow limits of the technology of the 1920s. Since Galvani’s discovery of the spark of life, models and metaphors have entered the human body in many ways; Mary Shelley’s *Frankenstein; or, the Modern Prometheus* (Shelley, 1818/2008) provided a blueprint still valid today for the way in which social and organic lifeworlds are transformed by research in science and technology.

The Brain as Communication Technology: A Humanist’s Utopia

The metaphorical appropriation of the body by electrical tools began with the simple analogy between cable and nerve fibre and provided the material basis for comparing the nervous system with telegraphy. In the later years of the nineteenth century, scientists had already begun to lament “this frequently used metaphor;” as, for example, psychologist Wilhelm Wundt wrote in his *Grundzüge der physiologischen Psychologie* (Wundt, 1874, p. 346). Speaking of the cable network as the “nervous system of the state”—or vice versa of the body’s “telegraphy system”—scientists and their audiences used the analogy in both directions (Otis, 2001). However, these intriguing analogies amounted to more than just rhetorical figures. Given the particular concerns of the nineteenth century for debates on time and progress, it may come as no surprise that such analogies were integrated into an evolutionary account of the history of technology, which claimed that all technological inventions could be traced back to biological principles. For the German philosopher Ernst Kapp, the similarities between biological and engineering solutions simply proved that technology in general was nothing but an unconscious externalization of the body’s intrinsic principles of operation, an “organic projection” as he called this mechanism of technogenesis (Kapp, 1877, p. 140). As a consequence of this process of externalization, the technological principles—and thus the biological operations of the body—become accessible to scientific exploration and intervention, setting in motion a process of open-ended perfection, a co-evolution of man and machine that has fascinated media theorists ever since. A century later and digesting the impact of the emergence of television, Marshall McLuhan reiterated Kapp with his famous statement:

> With the arrival of electric technology, man extended, or set outside himself, a life model of the central nervous system itself.  

*(McLuhan, 1994, p. 43)*

The idea of electric technology as the life model of the nervous system appears to be directly illustrated in a popular book dating from the mid-1920s. Here, the simple operation of a bell, for example, provided the perfect example of the reciprocal relation between biological model and its technical mirror image, because electrical impulses
travel through nerves and muscles the same way they proceed through the bell’s circuits (see Figure 5.2). In so far as this image showed two electric circuits—one in the outside world driving the bell and another inside the body driving the hand pushing the knob—it simply aligned body parts and technical details in a graphic explanation of common analogies; but it did not mobilize the technology to directly replace the body function. The electric magnet pushing and pulling the lever was depicted right next to the muscle and nerve, but it was still the biological muscle and not its electrotechnical counterpart that moved the finger. This was decisively different, however, for the brain where, in the image, room-sized switchboards stood in for the respective centers of volition and execution. In retrospect, the replacement of cognitive control with something limited like a switchboard hardly seems ingenious. Looking
back at an image such as this from the distance of three quarters of a century, one may smile at the naivety and simplicity of its technological solution. The heavy modernism of such images underlines their datedness today, since no biological structure ages as quickly as obsolete technology. Indeed, the telegraphy office was soon to be replaced by the computer and later the internet.

In its time, however, the point was less to postulate the brain as a telephone exchange than to elucidate an important aspect of its functionality by means of this analogy. Even for the most general audiences of the 1920s, it was quite evident that the brain was capable of processing many more and varied sensations than could be explained by the single analogy of the telephone. During the 1920s, new communication technologies such as the radio and film added further options for spelling out the functional identity of sensory processing and media technology (see Figure 5.3). The physiological processes when sitting in front of the screen in a movie theater, for example, could be formulated as the eyes taking pictures like a camera that were sent
to a processing station in the brainstem before reaching the visual center in the back of the head. These pictures were then projected on to higher visual centers further up front in the brain to be deciphered, before sending an impulse to the steering of the larynx. The question of what exactly was being shown pales here in view of the many amalgamations of body and technology that depict the human body as a wonderful machine which technology can scarcely touch.

The examples here are taken from Fritz Kahn’s magnum opus, the popular textbook *Das Leben des Menschen*, which appeared between 1924 and 1931 in five lavishly illustrated volumes with more than 1500 images. The book sold widely and enabled Kahn, a physician by training, a second career as a popular science writer, first in Weimar Germany and later, after his emigration, in the USA. Kahn’s recipe for success was the combination of a lucid style of writing with intriguing visuals portraying the body and its functions as machine ensembles. In this way, Kahn’s world of images and Kapp’s organ projection almost merged. Unlike Kapp however, Kahn reversed the explanatory strategy. While Kapp suggested that technical inventions were based on a preconscious familiarity with the functional principles of the human body, Kahn explained bodily structures and functions by comparing them with everyday technology—even if this reservoir of functional analogies itself required further explanation. Where Kapp—and later McLuhan—speculated on epistemic connections between technology and the body, Kahn made the body’s mysterious, organic interior familiar by means of common gadgetry, as if a form of techno-literacy had the potential to reconnect with the body’s machinery in new ways. The flood of images showed how the modern human would understand him or herself through the invention of technical devices. Very few may have known exactly how to operate a switchboard or any other of the machines depicted, but seeing them in operation secured the possibility of a perfect explanation. In the visual language of Kahn’s images, human beings would ultimately reveal their identity in the construction of sophisticated technology.

With his popular images Kahn visualized a romantic utopia of industrialization on two different levels. Firstly, human ingenuity in instrument making and machine building had allegedly reached a stage where machines epitomized the complexity of the human body and, secondly, the process of technological civilization should ultimately arrive at an enculturation of nature into technology (Borck, 2007). In this way Kahn extended the classical Enlightenment programme of cognitive self-reflexivity and moral autonomy to the body; technological advances enabled a radically new form of “know thyself”—the technological explanation of bodily processes. According to Kahn, this technological enlightenment did not undermine human freedom and liberty, but resulted in the utopia of a seamless functionality in truly perfected technology. Kahn’s machines did not leak or produce waste while the workers and operators diligently pursued their jobs; this was the happy paradise of industrial production.

**Form and Function Beyond Technology**

In the idea of a perfect technology, Kahn’s industrialization of mind and body met with another strand in the history of models that explained the brain’s functions: the logical machine. But before exploring this further, it is important to widen the
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To escape the technological determinism implicit in the arrangement of the chapter so far. Since the invention of the first true automata, machines have been debated as models of body and brain fairly independently of the underlying philosophical framework (Canguilhem, 1992). This is most famously exemplified in the dualism of René Descartes’ posthumous *De Homine* (Descartes, 1633/1972) in contrast to the radical materialism of Julien Offray de La Mettrie’s scandalous essay *L’homme Machine* (Jauch, 1998; La Mettrie, 1748/1912). Technological models, however, did not have a monopoly in the discourse on the nature of the living and the human body; and the current interest in the blurred boundaries between man and machine must not obscure the historian’s awareness of the fact that alternative arguments also attracted widespread attention. For many brain researchers of the early twentieth century, for example, it was out of the question that mind or brain should be meaningfully compared to a mechanical machine because of its categorically different biological nature (Harrington, 1996). This argument gained momentum after the publication of evolutionary theory and with discoveries in cellular biology. As a consequence, researchers revived older ideas of a unique and universal biological principle such as irritability or movement and created from them a remarkable psychobiology, linking highest mental functions to the most basic but specifically biological properties of primitive cellular organisms such as amoeba (Schloegel & Schmidgen, 2002).

The so-called protoplasmatic theory of life (Geison, 1969; Lidforss, 1915; Roux, 1915), for example, appealed to neuroscientists because such a monistic approach to the realm of living phenomena could equally be applied to the appropriation of substances by a microorganism as to the apprehension of sensations by neurons (Borck, 1999). In addition, this theory was very well suited to explaining learning and adaptation, phenomena chronically difficult to account for with the machine metaphor because of a lack of appropriate tools. In light of the protoplasmatic theory, in contrast, learning and memory resulted from the dynamic plasticity of the neurons in the central nervous systems which formed new connections in an endless process, while others were withdrawn—as in sleep or forgetting.

Among the proponents of such biological models of logical reasoning and cognitive action counted a number of prominent neuroscientists such as Santiago Ramón y Cajal (1895), Auguste Forel (1894), or Theodor Meynert. Meynert is particularly interesting here and deserves further exploration, because he began with an abstract and geometrical model for the brain as the basis for his theory of mind and only later combined it with the protoplasmatic theory of brain action. His case hereby underlines the manifold metaphorical resources upon which neuroscientists drew for their comparisons and it illustrates how different analogies could be combined in more complex models—in this case all non-mechanical.

Initially, Meynert argued for the perfection of the brain on the basis of its geometrical shape, by linking it to a sphere that Plato had already identified as the form of perfection. To this macroscopic model, he added microscopic biological details. While he maintained that the nerve cell bodies that were located in the surface of the spheres were the seat of consciousness, Meynert differentiated the three different types of fibre that made up the brain’s fibrous interior: these were the sensory, receiving stimuli from the outside world, the motor initiation action, and the so-called association type,
building an internal communication structure within the brain itself. By means of this tripartite fibre system and the nerve cells themselves, the brain formed a special instrument of apperception, association, and projection. The anatomical structure, Meynert concluded, provided the physical basis of the brain’s cognizing operations (Meynert, 1865, pp. 48–55); this was Meynert’s basic conceptualization of the brain as a psychological apparatus. Two decades later, Meynert superimposed as an active, functional principle the protoplasmatic theory onto this anatomico-physical model:

Just as the medusae stretch out their feelers into the world and take possession of their prey through tentacles, so this composite protoplasmatic being, which is the cortex, possesses centripetally-conducting extensions, the sensory fibers of the nervous system, which we may consider its feelers, and motor fibers, which are its tentacles.

(Meynert, 1884, p. 127)

The metaphor of a physical apparatus for projection and association translated anatomy into psychology whilst the protoplasmatic theory provided the basic, vital principle for describing such phenomena as the psychophysiologically active, neuroanatomical details.

For Meynert, who continuously refined the use of metaphors in his brain theory, the concept of ideal shape and of the protoplasmatic actions of nerve cells did not serve a merely rhetorical role, explaining an otherwise well defined physiological action (Black, 1962). Quite the contrary, the metaphoric models provided mere anatomical observations with their epistemic significance for brain theory (Hesse, 1966); thus, they were a crucial part in Meynert’s work as a teacher, scientist, and writer (Meinel, 2004). In fact, the model sparked further anatomical investigations, the metaphoric language of projection and association serving Meynert as a starting point for developing a specific brain preparation technique (see Figure 5.4). With this technique, he was able to demonstrate the different fibre types making up the connectivity within the brain as asserted by his theory (Guenter, 2009). In Meynert, the metaphors mediated back and forth between anatomy and meaning, in a spiraling process of the practical and the conceptual (Klein, 2003).

To map out the extent of the impact that biological and political metaphors have in brain theory (Draaisma, 2000) would be beyond the scope of this chapter, whose focus is on tools. But Meynert provides a good example of how neuroscientists relied on metaphors for explaining aspects of brain function and mental activity outside the realm of technological models. While Meynert engaged geometrical and biological models, others used tools specifically in order to highlight their difference to brains. The explanatory strategy of metaphors and models could thus be extended beyond the limitations of a particular technological model, when the very limitations explained the specificity of the brain, typically in terms of its super-technical functionality—as Penfield did with his differentiation of the human memory system from a standard phonograph or camera. In this way, the model could be utilized as an analogy together with a differentia specifica in order to demonstrate the superiority of the brain. In a similar tradition, the brain has been compared with various instruments of wonder such as, for example, a musical instrument (Kassler, 1994). The most famous of these—though not a musical instrument—is obviously Charles Sherrington’s
“enchanted loom,” which modeled the brain on what was then, technologically, a most complex machine, the Jacquard loom, “where millions of flashing shuttles weave a dissolving pattern, always a meaningful pattern though never an abiding one” (Sherrington, 1953, p. 178).

The master, however, of the strategy of explaining the psyche in technical terms beyond the physical space of a technological model, was Sigmund Freud. Arguing that the realm of psychic processes must not be conflated with the physical space of the brain’s anatomy, Freud broke with both the reductionism of the machine theory and the monism of psychobiology thereby transforming the traditional ontology of Cartesian dualism to the epistemology of psychoanalytic theory. As a well versed writer and with a solid grounding in the nineteenth-century neuroanatomical tradition of his teacher Meynert, Freud used analogies and technological models for elucidating the flaws of any naturalistic theory of the brain (Borck, 1998). He mobilized models and metaphors precisely as imperfect tools, which can be studied in his many strategic comments on the limits of particular visual metaphors and functional analogies.

A famous example is Freud’s comparison of the psyche with the city of Rome in Civilization and its Discontent (Freud, 1930/2001). The point of comparison is not the large number of ancient buildings, nor their existence to this day, but the very non-imaginability of a Rome that has been preserved in all buildings ever built there; such a city may be conceived of but can no longer be visualized. In order to gain clarity on its significance, the analogy has to be driven beyond the limits of visual representation. For Freud, the narrative quality and logical structure of language allowed access to the specific dimension of time—so central to psychoanalysis—in a
linguistic representation which built on the physical model but left it, metaphorically, behind. The pictorial language of the illustrations inevitably fell behind the mature concept, but this very failure illustrates the complexity of figurative thought. Freud’s concluding remark on the Rome comparison stressed his strategically inverted use of topographical metaphors (Freud, 1930/2001, p. 71): “Our attempt seems to be an idle game. It has only one justification. It shows us how far we are from mastering the characteristics of mental life by representing them in pictorial terms.” Freud developed a visual argument that the psychical apparatus can only be described in language and not represented by anatomical visualizations, because in his theory the psyche followed the structural logic of a symbolic space and not the anatomy of a geometrical topography.

A particularly telling example for this explanatory strategy and hence for the usefulness of technical models in psychophysiological brain research is given in Freud’s short Note Upon the “Mystic Writing-Pad” (Freud, 1925/1961) that inspired Jacques Derrida, in turn, to a long reflection about the primacy of writing (Derrida, 1961/1980). In his Introductory Lectures on Psycho-Analysis and elsewhere, Freud had compared the psychical apparatus with a microscope or telescope, and had already intentionally located the unconscious in virtual spaces such as the point of refraction (Freud, 1917/1971). In the Note, the psychical apparatus has finally become a little toy, a writing pad. Carefully, Freud studied the various details and layers of this child’s toy, comparing each with a somewhat similar aspect of the psyche. But, in the final step, Freud transcended the realm of material technology and moved from the physical model to the linguistic by reflecting on the assumed functionality of a truly “mystic” writing pad—which obviously the psychic apparatus is. Whatever the brain does, the psychical apparatus is a peculiar system for receiving, storing, and reactivating various kinds of traces written on its surface. For Freud, the psyche is an inscription device.

The Brain as Writing Apparatus and Symbolic Machine

While Freud speculated about writing as the primary psychic operation, electroencephalography allowed the brain to literally inscribe its activity onto paper. It seemed as if the world of brain structures, nerve fibres, and electric potentials would blend into the world of meaning, life, and sense (Borck, 2008). Brain wave recording may not have come with its own technological model, but it offered as an analogy for the brain’s workings a very powerful cultural technique. In retrospect, the absence of a technological model for the brain in electroencephalography proved particularly fertile ground, because it provided the necessary space for the computer, the most powerful brain model of the twentieth century, to later be inserted (Borck, 2005). Calculating machines had their very own history of metaphors with the “brains of brass” dating back to long before the availability of the first electric machines with thousands of vacuum tubes and “computing” as a professional field (Spufford & Uglow, 1997).

The next step in blending brains and computers followed on theoretical grounds when Alan Turing formulated a simple, yet universal, algorithm of problem solving
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(Turing, 1936) and McCulloch and Pitt described the circuitry of logical neuronal nets (Kay, 2001; McCulloch & Pitts, 1943). Later, machines became available that used electricity for logical operations and calculation, and the gap between the world of material processes and symbolic action appeared to have closed (Latil, 1956). From this moment on, brains were discussed as biological instantiations of such machines; brains had become computers.

In addition, the interdisciplinary evolution of cybernetics—the thinking in terms of “control and communication” across the mechanical–biological divide so fashionable shortly after the end of World War II—provided the perfect framework for a new wave of brain modeling in terms of control technology and steering devices, from W. Ross Ashby’s *Design for a Brain* to John von Neumann’s theory of automata (Ashby, 1954; von Neumann, 1966). Others like the British cybernetician William Grey Walter indulged in soldering and tinkering with simple electro-mechanical creatures that mimicked human behaviour (Hayward, 2001; Walter, 1953). As Walter demonstrated with his famous tortoises, intentionality and teleology could already be perfectly simulated by means of basic mechanical devices. There was no divide between physical, biological, and psychological processes.

Although computers were still immobile, garage-sized technological systems that did not physically resemble the brain, they quickly dominated brain theory. According to Norbert Wiener, brains resembled computers not only with regard to their calculation capabilities, but even in that they used a similar mechanism for data processing. Computers used electricity for their operations just as neurons communicate by electric impulses as physiology had revealed; similarly there was a correspondence between the all-or-none principle and the digital code in the computer, as the inventor of the word “cybernetics” pointed out when he became interested in brain waves (Wiener, 1961). Whilst Wiener’s idea did not really stand up to scrutiny, it was not the last time that brains would be mistaken for computers during the twentieth century (Churchland & Sejnowski, 1999). The computer dominated much of brain research and the public understanding of mind and brain throughout this period. Paradoxically, the celebrated victory of IBM’s Deep Blue over Kasparov in 1997 made the hitherto deeply engrained analogy of brain and computer look superficial and falter, coinciding as it did with an increasing awareness of the machines’ clumsiness in doing something beyond calculation, for example bodily movements. Today, only 10 years later, it is already hard to reconstruct how it was that the computer so easily assumed the role of central metaphor in brain research over such a long period of time. Maybe one day we will look back on the computer as the most convenient and common form of misunderstanding the brain in modern history.

The computer was not, however, just one more step in a long sequence of models (although it is this too). In a certain sense, the universal logical machine was the ultimate model that, up to now, has proven irreplaceable. What newer tool or gadget could possibly replace it? What could stand in as the next, central metaphor? The iPhone can be said to be much more versatile than the desktop computer, let alone the room-sized forerunner with which this analogy began; in addition it symbolizes a trend towards ubiquitous computing—human beings also have the option to use their brains in every situation, wherever they find themselves. Nevertheless, the iPhone does not suit as the up and coming model of the brain, because, in essence,
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it is just a handsome tool that ill fits the status of human nature’s mirror image. Similarly, the worldwide web is sometimes said to be the brain’s next top model (Mayer-Kress & Barczys, 1995), and yet with its physical dispersion, the internet is too intangible to serve as a model as the computer once did. If this trend holds, the entire strategy of analogizing brains with tools appears to be entering a new phase with the expiration of the computer metaphor. Ironically, the computer seems to have lost its significance as comparative tool in spite of its qualities of availability and versatility—as if its epistemic value as central icon waned in reverse relation to its omnipresence.

The Plastic Brain: What You See is What You Get

With the disappearance of the computer metaphor, the model changed sides and became a tool. For a long time the computer has proved indispensable for brain research, though no longer as cognitive resource but as technical instrument. This transition marks more than just an episode in the history of the brain; it is the end of the history of the brain machine (Jeannerod, 1985). The decline of the computer as central metaphor (which worked well as long as the emphasis was on functional similarity rather than physical resemblance) coincided with a second, potentially more significant cultural shift, which may have accelerated the first: the rise of a new visualization technique to the status of most prominent research methodology.

Functional imaging currently attracts enormous attention among the scientific community and the general public alike, because it allows the simultaneous visualization of structural as well as functional details in a single image, showing distinctively task-specific brain activation. Functional brain imaging has opened a new chapter in the history of brain research—the entry point of “brainhood,” the positioning of the neurosciences as the universal frame of reference for addressing human nature (Vidal, 2009). The availability of this method for studying basic neurophysiology in relation to complex cognitive tasks and fundamental philosophical questions has certainly contributed to the shift in research towards higher mental functions and the emergence of such new fields as social neuroscience or neurophilosophy. In addition, the new imaging culture of isolating specific brain areas as the centers for particular psychic functions has also fostered a renaissance of localizationism—quickly denounced by some as “neophrenology” (Uttal, 2001). The precision of spatio-temporal information regarding brain activation facilitated an ontologization of different brain states by replacing the functionally abstract view of the brain-as-computer model with the concreteness of “the brain at work” (Hagner, 1996).

Another dynamic triggered by this technology is perhaps more problematic with regard to its socio-epistemic implications than the fragmentation of psychic processing into discrete units. The revived localizationism replaced the mediation of metaphors and models with the immediacy of an artificially real brain image, allegedly revealing the functional activity of the psyche within the brain. The debate about the shortcomings of particular models for the brain, or the appropriateness of the machine metaphor in general, appears to be nostalgically futile and pointless now that the neurosciences can offer human societies brain images instead of machine models.
Models and metaphors may fail or betray, but they typically operate in the differentiality between the object and the concept, while images as objectifying representations always already tend to conflate the object with its representation. Here the future challenge for the neurosciences emerges. While psychoanalysis—as well as cybernetics—operated in an uncertain zone beyond the ontology of Cartesian dualism, the new imaging sciences engage the epistemological reductionism of materialist approaches but, at the same time, increase ontological complexity by constructing ever more subtle substrates of emotional, social, or cognitive states (Pickersgill, 2009). Brain research has thus moved into a space that Paul Valéry once characterized as “the interior of thinking” where there is “no thinking” (Valéry, 1973, p.124). Today, all kinds of fascinating brain images invite us to take false-colored pictures from the interior of thinking as an answer to the question of what thinking is. Ironically, the neurosciences transferred mental life onto the screen with the slogan “we are our brains;” the realism of the images testifies to the enormous effort to turn brains into media machines.

Once, metaphors and models participated actively in the neuroscientific research process; they inspired new, experimental approaches that resulted in technological tools or new models and they mediated the significance of such undertakings. Metaphors and models operated as multiple mediators in the zone where nature and culture articulate. In short, metaphors and models shaped the “neuroculture” of each period of brain research. Their multiple functions were essential in generating fresh perspectives in brain theory and in pointing to new directions for research. If today we “are” our brains, this mediation has been made redundant and the brain has become the medium and message. This points to a major cultural transformation compared to the long history of the machine paradigm that thrived on the very difference between proposed theory and the generally shared view—it was only a metaphor. From Descartes and LaMettrie to McCulloch and Walter, the specific potential of any metaphor or model—as well as its potentially scandalous nature—resulted from the shared assumption that being human, living as a person, meant something different than having a brain. This crucial difference between the model and that which it models is being eroded in the raison d’être of our present neuroculture. Ever more perfect visualizations and simulations characterize current practice in the neurosciences where the artificial has become indiscriminately real, animated, and alive.

The neurosciences, however, are a vast and dynamic field, which will continue in all likelihood to churn out surprising effects beyond today’s imaginings. The sheer vastness and heterogeneity of the field seems likely to prevent the neurosciences from imminently uniting under a single paradigm and coherent brain theory. The very progress of the neurosciences undermines any stable sense of explaining mind, brain, and psyche. In a few decades, others will smile at today’s naiveté. The real challenge in brain research is not to mistake today’s solutions for the final answers. If the realism of today’s world of imaging has replaced older modeling fantasies, then a new need for appropriate metaphors arises in order to maintain society’s creative and humanistic potential against the perfected brain media of what-you-see-is-what-you-get. Models and metaphors obviously differ greatly in their liberating potential, their political overtones and individual or social grounding. The metaphor of the computer, for example, inspired the typically male fantasy of an intellectual life as pure information processing to be preserved electronically in the spaces of large technological systems.
Later the stipulated hard-wiring of the brain in conjunction with the rise of genetic determinism mirrored the rigidity of the Cold War era. More recently, the emphasis shifted towards neuroplasticity and neuroenhancement, now calling for new training strategies and smart drugs.

Where is the true place for imagination in the polarity between the potentialities of plasticity and the reductionistic realism of neuroimaging? The Library of Babel, Louis Borges’ wonderfully claustrophobic novel, encapsulates a potential answer (Borges, 2000). In one reading, any book is just a predeterminate sequence of letters; every possible book has already been written and sits on a shelf in Borges’ library. Another meaning of the same metaphor starts with the active process of reading rather than the ready product of the book. Since reading is a creative act that activates a text and constitutes a new meaning each time, no book is a mere representation of something already given but an opening (Haverkamp, 1996). Metaphors are more than just rhetoric; they are linguistic tools for finding orientation in complex worlds, as Freud and Sherrington masterfully demonstrated with their imaginative metaphors that push brain theory beyond representation. In today’s neuroculture, the responsibility has shifted to the neuroscientists to keep alive the metaphors we live by.

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