In the Eye of the Beholder: The Role of Style of Thought in the Determination of Health Risks from Electromagnetic Fields

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Abstract

The dispute whether some environmental electromagnetic fields (EMFs) are human health hazards has continued to grow despite a large research effort by government and industry to find facts that would resolve it. I suspected that the dispute was mostly based on a conflict regarding what the disputants thought a scientific fact was, rather than a lack of facts. This idea was examined by empirically determining the kinds and characters of scientific fact. On the basis of representative sampling of the world-class scientific literature, I found that modern science consisted of five different kinds of scientific facts, only two of which fueled the EMF dispute. The dispute could be partially understood as a disagreement regarding which of the two kinds of facts ought to form the principal basis for resolving the question. EMEs in the environment can be health risks in the biological thought-style, depending on the non-empirical rules chosen for making abductive inferences concerning the meaning of pertinent studies. Because there are no scientifically correct rules, they can be chosen only on the basis of purpose or policy. EMFs cannot be a health risk in the physical thought-style because that conclusion cannot be deduced from accepted scientific laws.

Introduction

Having spent a lifetime in biomedical research, it seems to me that no textbook definition or philosophical explanation of research adequately captures how it is done or what it produces. Attempts to do so relate to what I do like definitions of democracy relate to what you see. The essential thing I find missing in the standard characterizations of biological science is an explicit recognition of the material role of the human will in judgments of what a scientific fact is. Thinking in this way prompted me to ask: from an empirical perspective, what is a scientific fact? My ultimate motivation was to understand how it could seem to me that electromagnetic fields (EMFs) such as those from power lines and cell telephones are a health risk was a biological fact, and clearly so, while others strongly denied that the statement had the ontological status of a fact.[13]

My hypothesis for this study was that there are fundamentally different kinds of scientific facts, and that basing arguments primarily on one kind of fact partially accounted for the disagreement concerning EMF health hazards.

Types of Scientific Facts

I assumed that, whatever scientific facts were, examples of them would be manifested in the pages of the prestigious journal *Science.* My approach was to regard the conclusions of the journal s reports as stating facts about science, and then to inquire into their character, looking for patterns. The advantages of this approach were that it was empirical and that most scientists would probably agree that what was in *Science* was a fair basis upon which to evaluate the species of facts in modern science. In principle, there could have been some kinds of scientific facts that simply did not appear in *Science*, but that seemed unlikely.

I randomly chose Issue No. 5248, which contained 16 reports and was published January 26, 1996, and I found three types of factual conclusions in it (Table 1). One type was discovery of a tangible fact, either a molecule, a method, or a virus. The other types involved the inference of conclusionary facts by means of deductive or abductive reasoning (Figure 1). There were two additional kinds of scientific facts in the issue, although neither kind was a direct conclusion of a report. Most reports contained measurements, perhaps the most elemental of all scientific facts. No report in the issue contained a measurement of such significance as to warrant publication, however perusal of subsequent issues of *Science* showed that measurement facts alone could occasionally be sufficiently important to merit publication. Finally, the general principles from which the deductions in Issue 5248 were made were necessarily assumed to be scientific facts, and they could only have been formed by an inductive inferential process (Figure 1). Only rarely (in the area of subatomic physics) did *Science* publish reports in subsequent issues that contained conclusionary inductive facts.

Table 1. The three kinds of conclusionary facts contained in *Science* Issue 5248.

DISCOVERED FACTS

References	Discovery
4	Organic molecule
5	Inorganic molecule
6	Dating method
7	A virus

DEDUCED FACTS

References	Covering Law	Phenomenon Explained
8	Physical theory	Energy dissipation
9	Physical theory	Structure and stability of liquids
10	Heuristic rate equations	Stabilization of atmospheric oxygen
11	Heuristic rate equations	HIV clearance from blood
12	Heuristic algorithm	Serine protease diversity

ABDUCED FACTS

References	Cause	Effect
13	Decreased cyclin-E/CDK2 activity	Loss of anchorage
	Increased CDK inhibitors	Decreased cyclin-E/CDK2activity
14	Osteopontin	Activation of CD44 receptor
15	Vigilance	Increased brain blood flow
16	Mutant enzyme and Cu^{2+} chelation	Altered catalysis and cell growth
17	High density lipoprotein	Activation of SR-B1 receptor
18	ALG-2, ALG-3 genes	Apoptosis
19	NMDA receptor	Auditory learning

Deductive and Abductive Facts

Neither discovered (in the sense described in Table 1) nor induced facts have been at the heart of even one case of a dispute regarding EMF risks and, with minor exceptions, neither have measurement facts. Consequently, neither discoveries, measurements, nor inductions could have formed the basis of the presently-held polar opposite views regarding EMF health risks. With deductive and abductive facts, however, the situation was quite different, and therefore they merited closer scrutiny.

A report that dealt with rupturing of adhesive bonds formed by short-chain molecules was typical of those that employed deductive reasoning.[8] A model was adopted that involved 2 walls containing 800 atoms each, coupled by stiff springs in a face-centered-cubic lattice; the space between the walls was occupied by 128 polymer chains that each contained 16 molecules of a given mass. Equations based on physical theory (electromagnetism and energy conservation), assumed forces (introduced in the guise of potentials), and numerical values of particular parameters in the equations were regarded as jointly controlling the process of rupturing of bonds between the polymers. In simulation, the

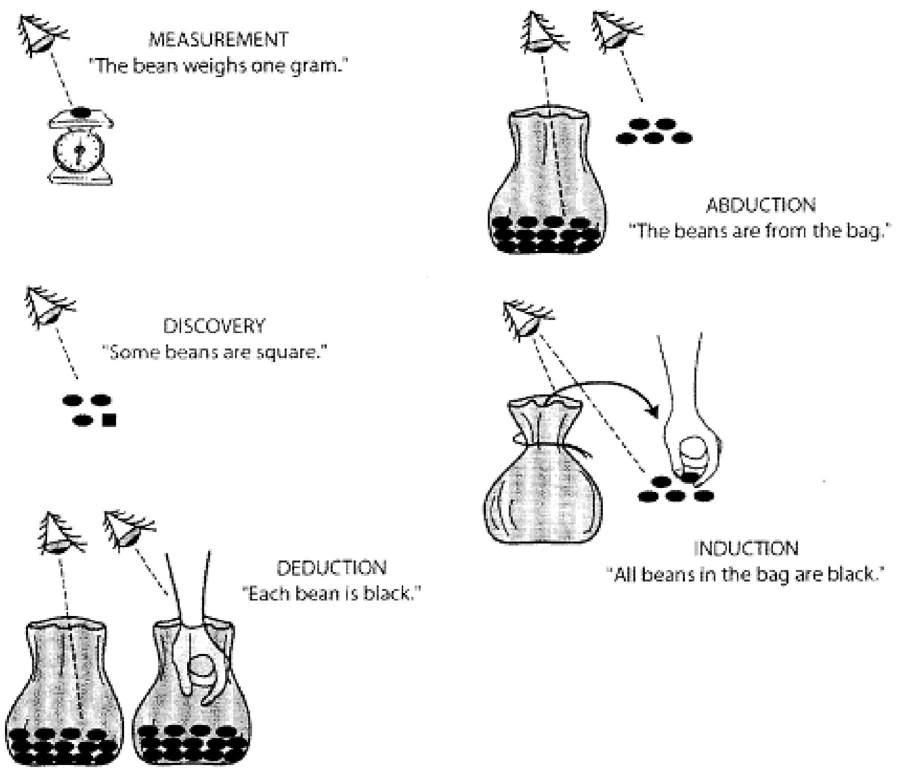

Figure 1. These are the fundamental kinds of scientific facts. In deductive reasoning, the observer sees that all beans in the bag are black, and that the beans came from the bag. Under these conditions, it can be concluded that any bean withdrawn from the bag must necessarily be black. Deductive reasoning is the canonical reasoning form in the physical sciences, which presuppose knowledge of a mathematical law that compels phenomena to occur in the manner actually observed. In abductive reason-ing[22] the observations are that all the beans in the bag are black and that some beans are not in the bag. If it were true that the beans came from the bag, that fact would explain why they are black. Thus, an assertion that the black beans are from the bag is reasonable, given the observations, but it is not proven in the sense of being deductively certain because it is logically possible that the beans could have come from some other source. An abductive argument does not prove a claim, it simply supports it. The marker for abductive reasoning is the word suggests: in modern terminology, the inference would be that, The data suggests that the beans came from the bag. Abductive reasoning is the canonical reasoning form in biology (see Table 1). In inductive reasoning the observer sees beans being removed from a bag, and sees that each removed bean is black. If the bag is large and many beans are removed, all of which are black, there comes a point when the inductive statement, All beans in this bag are black is justified.

walls were maintained at different temperatures and then separated from one another at different velocities, and it was shown that energy dissipation occurred by means of viscous forces at high temperature but by particular structural rearrangements of the polymer chains at lower temperatures. The authors argued that since the behavior of the model was similar to the behavior of some real systems, it is possible that the behavior of some real systems was actually caused by the forces postulated in the model, and that the molecular sequence of events in the real systems (which cannot be seen directly) was identical to that described in the model. If so, the authors reasoned, then the behavior of the real systems could be explained in the sense that it could be deduced from a governing law as a result of a particular cause (the force) via particular temperature-dependent mechanisms. The common factor in all the deductive studies listed in Table 1 was that the authors regarded the phenomenon of interest as governed by mathematical equations (covering laws).

The abductive studies contrasted sharply with the deductive studies. A typical example of an abductive study was the report dealing with why normal cells usually do not grow when they become attached to a substrate.13 attachment caused a growth in the cells in the sense that, given a requisite set of conditions, addition of the condition of attachment resulted in growth (but-for causality). The authors showed that decreased activity of the cyclin E/CDK2 complex occurred in cells grown in suspension. They argued that the decreased activity could have caused the anchorage independence. The same reasoning was then applied to consideration of the causes of the decreased activity. The authors showed that increased concentration of CDK inhibitors and decreased phosphorylation of a particular amino acid occurred in association with the decreased activity, and concluded that one or both of these factors could have been the but-for cause of the decreased activity. The authors, as well as those of the cause-and-effect studies, rationalized the causal relation by means of an abductive argument. The term most frequently employed in the reports to describe the link between the study results and the putative fact was suggests, but many other euphemisms were used including: indicate... ; ... may have been instrumental... ; ...not unreasonable ; results in... ; ...°may be one of the mechanisms ; °consistent with ; provide direct evidence for... ; is the most likely ; is involved in ; raised the possibility ; ...°believed that... ; ... may underlie ; ...provide insight into ; support a determining role ; orchestrated ; does not readily account for ; showed ; and confirmed the role of .

Thought-Styles

Insight concerning how the EMF dispute might be accounted for in terms of a dichotomy between deductions and abductions can be gained by considering the present state of deductive knowledge regarding EMF bioeffects. At the present state of development of physical theory, a judgment that environmental-strength EMFs can cause biological effects is impossible because no plausible model exists for the interaction of EMFs and biological systems that can be manipulated to yield such a result. In other words, because deduction from covering laws in the ordinary manner of physics is not possible, from the physicist s point of view (or from the point of view of anyone else who regards bona fide scientific facts as deductive in nature) there are no scientific facts that can support an inference that exposure to EMFs is a necessary and sufficient cause of biological effects of any kind, including effects on human health. Within the physical thought-style, therefore, a judgment that environmental-strength EMFs can be a hazard to human health is merely an assertion, not a scientific fact.[13]

The biological thought-style, in contrast, is based on abductive reasoning and accredits as scientific fact abductive inferences from valid cause-and-effect studies (see Table 1). Facts are recognized as such on the basis of empirical data rather than on the relation of data to theory. If the biological thought-style were chosen as the framework for deciding whether exposure to EMFs was a health risk, the substantive decision ultimately would be made on the basis of abductive generalizations from empirical data consisting of relevant but-for causes. Thus, within the biological thought-style, it is possible that EMFs are health hazards, depending on one s opinion of the but-for studies (see below). The opinion of the physicist that any conclusion affirming the existence of risk is unwarranted is an irrelevant opinion when assessed from within the biological thought-style because almost all biological (that is abductive) facts are deductively unjustified, and hence are not facts to the physicist. I conclude, therefore, that an internecine conflict between scientific thought-styles partly fuels the EMF dispute.[13] To the extent that it does, the dispute cannot be resolved by analyzing facts, but only by choosing the thought-style that yields the kind of facts thought to be pertinent to the problem.

Non-Empiricism in Abductive Reasoning

Even if there were no physicists and no claims that deductive facts were paramount,[13] this study suggests that the non-empirical dimension of abductive facts would still probably be sufficient, by itself, to ignite a dispute regarding EMF health hazards. To see why, consider the abductive fact urged by the authors that decreased cyclin-E/CDK2 activity caused loss of anchorage.[13] Assume that another group performed a similar study, but did not find such a relationship. Would the abductive conclusion suggested by the original authors now be less reliable? If replicability were regarded as the hallmark of scientific validity, then the failure to confirm the initial results could be viewed as casting doubt on their reliability. But it could also be argued that the failure to find something is not necessarily good evidence that the thing sought does not exist and that, consequently it is not reasonable to always allow a negative report to undercut the reliability of a positive report.

In actual scientific practice, the attitude adopted toward a mixed state of evidence usually depends on the interests of the person or group deciding the significance of these mixed results. An author of a review article, typically, might hedge a decision (the data is conflicting, and no firm conclusion is possible). But there will be others who must take a position, perhaps because one conclusion or the other would materially influence the design of their experiments. Ordinarily, in resolving the question, many factors would be considered including extent of the faith in the ability and honesty of the investigators, the reputation of the laboratories, whether the laboratories were in industry or academia, the track record of the investigators, insider information, style of presentation of the results, the relative prestige of the investigators institutions, and perhaps even the nationality of the investigators. The point is that, in the face of mixed results, which is commonly the case, the cognitive value of the scientific evidence in a particular area depends on who is evaluating it, why he is doing so, and how he does it. There is no necessarily right or wrong means of performing these analyses.

As another example, consider the conclusion that vigilance caused an increase in brain blood flow.[15] Assume that exactly the same change in blood flow occurred when subjects were exposed to EMFs. To avoid the difficulty of mixed results discussed above, assume further that the study was replicated many times, and always with the same result. Would such evidence indicate the existence of a health hazard to individuals exposed to environmental EMFs? Because a change in blood flow accompanies every cognitiveact and every sensation, it could be argued that changes in brain blood flow caused by EMFs were normal physiological responses, and thus not hazardous. On the other hand, a change in blood flow also accompanies every pathological change and perhaps the rule should be that it would be better to err on the side of caution and tentatively regard the exposure as a hazard, at least in the case where the exposure is involuntary. Again, the validity of the scientific inference depends on the reasoning principle chosen.

This analysis shows that acceptance of a claim as an abductive fact and, for even a greater reason, formation of a biological generalization, such as extrapolation of animal and human data to form judgments regarding health risks, fundamentally involves non-empirical elements. They cannot be chosen scientifically, but only on the basis of policy or purpose. Whatever particular measurements may suggest to one investigator, may not be what they suggest to another. This non-empirical element is simply not present in any significant degree in the thought-style that leads to deductive facts.

EMF Health Risks and Public Policy

Not all those who performed or analyzed the but-for EMF studies accepted the same policy and had the same purpose. The unsurprising result is that disputes regarding EMF hazards occurred within the biological thought-style.[20] Different investigators made different choices of rules for extrapolating the results of studies to environmental exposure of human subjects, leading to widely differing judgments regarding the extent of the risk. The conflicts that resulted from differing choices of non-empirical reasoning principles were particularly acute in epidemiological studies. In these studies, hugely and explicitly non-empirical decisional principles such as Koch s postulates and Hill s criteria were used, and each investigator reached idiosyncratic judgments regarding what the criteria meant and how they should be employed to rationalize a claim as a scientific fact, or to defeat such a rationalization.[21] Clearly, standardized criteria are needed to determine when the evidence is to be considered sufficiently developed to accept the idea of an association between EMFs and disease as a scientific fact. In the absence of such criteria, the issue of EMF health risks remains perpetually unsettled.

In summary, in the biological thought-style, both data and reasoning principles must be used to rationalize judgments regarding what constitutes scientific fact, and EMF biological research is no exception.[21] The principles provide a determinative frame of reference in the biological thought-style that is akin to the function of covering laws in the physical thought-style; they are necessary to guide and organize data into a coherent, self-consistent structure capable of being recognized and accepted as scientific fact. The principles themselves cannot be determined by the data, but rather must be chosen on a non-empirical basis. Different choices can result in different and possibly mutually contradictory judgments regarding what constitutes a scientific fact.

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Something has to be added to the laws of physics and chemistry before the biological phenomena can be completely understood.

Werner Heisenberg