REALISM WITHOUT TRUTH: A REVIEW OF GIERE'S SCIENCE WITHOUT LAWS AND SCIENTIFIC PERSPECTIVISM

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An increasingly popular view among philosophers of science is that of science as action—as the collective activity of scientists working in socially-coordinated communities. Scientists are seen not as dispassionate pursuers of Truth, but as active participants in a social enterprise, and science is viewed on a continuum with other human activities. When taken to an extreme, the science-as-social-process view can be taken to imply that science is no different from any other human activity, and therefore can make no privileged claims about its knowledge of the world. Such extreme views are normally contrasted with equally extreme views of classical science, as uncovering Universal Truth. In *Science Without Laws* and *Scientific Perspectivism*, Giere outlines an approach to understanding science that finds a middle ground between these extremes. He acknowledges that science occurs in a social and historical context, and that scientific models are constructions designed and created to serve human ends. At the same time, however, scientific models correspond to parts of the world in ways that can legitimately be termed *objective*. Giere's position, *perspectival realism*, shares important common ground with Skinner's writings on science, some of which are explored in this review. Perhaps most fundamentally, Giere shares with Skinner the view that science itself is amenable to scientific inquiry: scientific principles can and should be brought to bear on the process of science. The two approaches offer different but complementary perspectives on the nature of science, both of which are needed in a comprehensive understanding of science.

Key words: science, verbal behavior, epistemology, radical behaviorism, perspectival realism

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Views of science have changed significantly over the past century. The first half of the 20th century was dominated by logical positivism and classical operationism, which defined science in relation to testable propositions formulated in logical-deductive terms. Science was seen mainly as a theoretical activity, with experimentation serving a necessary but subsidiary role. The second half of the century was characterized by a growing emphasis on science as action, as the collective activity of scientists behaving in a social and historical context. By this view, science occurs not in some idealized world of logic and reason, but in the real-life behavior of scientists acting in socially coordinated ways.

This science-as-process view has given rise to a wide range of viewpoints on the nature and scope of science. While there is now general agreement that science is composed of human acts—observing, measuring, describing, mod-

eling, interpreting, and so on—occurring in social contexts—laboratories, universities, professional societies, funding agencies, and the like—there is little consensus on how best to conceptualize and understand the process of science. Merely acknowledging that science is a human social endeavor provides few clues about the kinds of processes involved in the conduct of science. How does science work? Why is it so successful? What is the nature of scientific knowledge? How, if at all, does scientific knowledge differ from other forms of knowledge? What is a scientific fact? How do facts differ from theories, and theories from laws? Indeed, does it even make sense to speak of laws in any traditional sense? And once science is contextualized and social factors brought into focus, what becomes of objectivity, rationality, and truth—the hallmarks of traditional scientific inquiry?

These are the kinds of questions addressed in two recent books by Ronald Giere, *Science Without Laws* (1999) and *Scientific Perspectivism* (2006). Giere is a philosopher of science who situates his work within the field of science studies, an interdisciplinary endeavor aimed broadly at understanding the process of science. Within this rather eclectic mix of perspectives on science, Giere's stands out in

part for its insistence that a rational rendering of science is both possible and desirable. Giere's perspective shares important common ground with Skinner, whose longstanding interest in pursuing a scientific understanding of science comprised a key aspect of his *radical behaviorism* as a distinctive philosophical position (Skinner, 1957).

A basic tenet of radical behaviorism is that knowledge of the world, including scientific knowledge, is behavior with respect to the world. To understand scientific knowledge one should be looking at actual scientific behavior rather than normative behavior that fits some preconceived notions of science. This was the main message of Skinner's (1956) essay, *A Case History in the Scientific Method*, a self-portrait of the behaving scientist. Standing in opposition to the classical view of the dispassionate scientist applying the scientific method to uncover Laws of Nature, Skinner reformulated science as behavior in a social context, and attempted to explain the conduct of science in terms of what is known about human behavior more generally.

Although Giere identifies his work as falling broadly within the cognitive sciences, his general approach bears greater resemblance to Skinner's writings on science, and to contemporary experimental work in behavioral laboratories, than to conventional cognitive theory and research. Like Skinner, Giere attempts to explain science not only in terms of the behavior of the individual scientist but of the social conditions that give rise to and maintain scientific activity. Also like Skinner, Giere regards scientific activity as part of the natural world, as part of the world to be explained using natural-science concepts and methods. At root, Giere's is a naturalistic approach to understanding the conduct of science that advocates the use of scientific methods and principles to understand science. The approach attempts to bring what is known about science to bear on questions of why science works and why it is so successful.

In this essay I review Giere's two books, identifying points of convergence with Skinner's writings on science. I begin with a synopsis of the two books and of Giere's position, *perspectival realism*, followed by an overview of Skinner's writings on science. I will attempt to show that perspectival realism and radical behaviorism are not only compatible but are mutually supportive. They provide different but complementary perspectives on science, both of which are necessary in a comprehensive naturalistic account of how and why science works.

GIERE'S PERSPECTIVAL REALISM

Science Without Laws (hereafter SWL) is a collection of 11 essays, most of which address various dimensions of a growing tension between different approaches to understanding science, what Giere calls ''the science wars.'' On one side is *classical science* (or ''enlightenment science''), according to which science is the rational pursuit of Universal Laws of Nature. By the view, the world can be known objectively, and Truth follows as a logical consequence of applying the scientific method. On the other side is a newer approach called *social constructivism*, according to which human conduct—including the conduct of science—is a social process; as such, science cannot be separated from human values and beliefs, and is therefore no more ''objective'' or ''true'' than any other human endeavor.

Giere finds both positions untenable, at least in their more extreme forms, mainly because they fail to capture what scientists actually *do*—they are poor models of scientific activity. In their place, Giere offers a more nuanced and behaviorally sophisticated approach that finds a middle ground between classical and social constructivist views of science. He gives each their due, but also points out serious flaws in extreme versions of either view. He recognizes that science is indeed a social process (as claimed by social constructivists), but that scientific models nevertheless bear an objective relation to the world (as claimed by classical science). Giere shares with classical enlightenment science the realist view that there is a real world out there independent of our responses to it, but at the same time, shares with social constructivism the view that social circumstances can alter our contact with that world, and hence our ''perspective'' of it.

According to Giere, the social constructivists are correct in emphasizing the social conditions of science (as the collective activity of scientists). But they go too far by equating scientific knowledge with all other forms of

knowledge. According to the more extreme versions of social constructivism, the products of science—its methods, models, and explanations—are constituted (literally brought into existence) through social relations between people, and are maintained by social convention. Because social conventions—even widely adopted social conventions—change over time, there can be no absolutes, moral or scientific. Science is one way—but not necessarily the only way or the best way—to understand the world. In its most extreme forms, this leads to a pluralistic and relativistic approach that grants equal time to any and all approaches to human knowledge: Astronomy and astrology are different but equally valid conceptions of the universe.

Giere finds this kind of murky relativism misguided and potentially dangerous, at one point calling it "sheer postmodern madness" (SWL, p. 60). It is a gross oversimplification of complex social processes that obscures rather than clarifies the nature of science. Science has distinctive practices that maintain distinctive ways of knowing about the world, practices that have yielded remarkable advances in our understanding of and control over nature. As a result of the special practices characteristic of science we know about planetary orbits and about the structure of DNA; we know about the dates of fossil records and about chemical weights of elements; we know about cellular organization and about the structure of atoms. That these are useful things to know about cannot be seriously questioned. To be sure, the reasons these are important things to know about the world is a product of our collective experience as social beings (one might say, our cultural values). But given that truism, one cannot dispute the existence of genuine scientific knowledge:

> I intend such [scientific] expressions in the relatively ordinary sense that scientific knowledge is knowledge *of the world* and that there is a difference between knowledge and mere opinion, even widespread opinion. (SWL, p. 3, italics in original)

Giere views scientific knowledge as progressive and speaks unapologetically of scientific advances (something social constructivists are reluctant to do). He takes scientific facts pretty much at face value, too, while recognizing that the criteria for calling something a fact changes over time and in relation to prevailing practices of the verbal community. There is no denying that scientific knowledge is a social product. But to acknowledge that social conditions are in part responsible for scientific knowledge is not to make it any less real. While the development and use of telescopes obviously reflects human social interests, the orbits of the planets do not. It is one thing to regard science as a social process, and another thing entirely to regard the facts of science as socially fabricated. As Zuriff (1998) has noted, there is a difference between the social conditions responsible for scientific facts and the social acceptance of such facts. Thus, science may indeed reflect prevailing cultural values, but this in no way detracts from meaningful and effective contact with the world.

Giere's approach, *perspectival realism*, finds a middle ground between the extremes of the context-free universals of classical enlightenment science and the value-laden particulars of social constructivism. In acknowledging the existence of a real world, and of meaningful contact with the world, Giere's perspectivism is genuine realism, but it is a type of realism with a social edge. It acknowledges that science does indeed occur in a social context; this does not mean that all social contexts are equivalent, however. Scientific contexts encourage a particular type of contact with the world—a perspective on the world—that can legitimately be termed *objective*.

Giere's more recent book, *Scientific Perspectivism* (hereafter SP), is a more focused elaboration of his position in relation to basic perceptual functioning, to scientific observation, and to scientific theorizing. To illustrate how perspectivism is basic to perceptual functioning, Giere uses the example of color vision. Although commonsense understanding encourages a view of colors as inherent features of objects, the science of color vision suggests a different view altogether. The redness of an apple is not a fixed property of the apple; rather, it is an interaction of certain chemical properties with human sensory systems that occur in the context of certain lighting conditions. Change any ingredient in this relationship and the redness changes, if not disappears altogether. The color, in other words, is a psychological property of the interaction between an observer and the world, and does not exist in either alone.

This does not imply, however, that objective responses to color cannot be established. Although dependent on sensory (and to some extent social) systems attuned to particular features of the world, the fact is that a majority of people responds similarly in the range of wavelengths we term ''red.'' Such constancies are a product of constancies in the world (objects with similar chemical makeup), constancies in human nervous systems (reflecting similar evolutionary pressures), and in the case of more complex discriminations, constancies in the contingencies arranged in human environments (reflecting similar verbal contingencies). To the extent that such responses are intersubjectively verifiable, we might call them ''objective.'' But objectivity, as defined here, is not a property of the world ''out there.'' Rather, it is a product of the interaction of the world with our nervous systems and our learning histories. Construed in this way, perspectivism is not incompatible with objectivity.

Perspectivism in Observation

Giere then makes a similar case for perspectivism in observation more generally, and scientific observation specifically. He begins with the assertion that most modern scientific observation requires instrumentation, a major function of which is to increase objective measurement of some aspect of the world. Instrumentation increases objectivity in the sense that it promotes similar responses from the standpoint of different observers, but it remains perspectival in the sense that all instruments respond to only a limited range of stimulation. As Giere puts it:

> Just as the human visual system responds only to electromagnetic radiation, so do ordinary microscopes or telescopes. These systems are equally blind to cosmic rays and neutrinos. But even for those aspects of the world to which they do respond, the response is limited. The human visual system responds only to electromagnetic radiation in the visual spectrum. A camera responds only to that radiation to which its film, or, more recently, its digital sensors, are attuned. Finally, even within their range of sensitivity, instruments, again like the human visual system, have some limitations on their ability to discriminate among inputs that are theoretically distinct. The relationship between inputs and outputs always remains to some extent a many–one relationship. The

nature of this relationship is part of the *perspective* of any particular instrument. (SP, p. 41–42, italics mine).

Giere uses the example of neuroimaging to illustrate how perspectivism operates within scientific observation. Although it is commonplace to view brain images as visual representations of the brain as it really is, Giere warns that such a view is fundamentally flawed. The images revealed through CAT scans, PET scans, MRI and the like are images mediated by the technology used to create them, and constrained by the human visual system. Moreover, there is no one correct or more accurate representation of the brain; it depends on one's goals. Consider the case of MRI.

> The choices regarding exactly which parameters to measure…and how to process them in the final image production are strongly influenced by considerations that often trade off speed of data acquisition against sensitivity to differences in tissue composition. There is no one ''right'' or ''best'' way to produce MRI images. There are many ways, all with their own virtues and shortcomings relative to various investigative aims. MRI, in particular, makes it abundantly clear that not only is scientific observation perspectival, but also that there are multiple perspectives from which one must choose and no ''objectively'' correct choice. A lot depends on the goals of the investigation at hand. (SP, p. 56).

Again, this should not be taken to imply that objective responses to the world are not possible, or that all perspectives are equally valid. Rather, it is to recognize that all views (even so-called objective ones) are perspectival, and that some perspectives may be deemed better than others in relation to accomplishing certain goals. It is important to reiterate, however, that ''better'' should be understood in a pragmatic sense of solving problems rather than in a realist sense of reflecting Nature. To Giere, success and progress in science are measured pragmatically, in terms of their practical effectiveness.

Perspectivism in Theorizing

Giere then proceeds to make a similar case for scientific theorizing itself, arguing that scientific theories are also fundamentally perspectival. A key concept here is a scientific model, which he calls the ''primary represen-

tational entities in science'' (SWL, p. 5). But unlike the classical view, there is no a priori assumption that the structure of a model must be similar to the structure of the world; only that it corresponds to or in some way represents the world. The notion of correspondence between verbal events and the world is thus retained from traditional realism, but here the correspondence is not taken as a given; rather it is to be resolved empirically. Conceived in this way a model is not True or False in some ultimate or logical sense. Instead, models are more or less accurate, more or less useful. If the concept of truth be retained at all it is the usual everyday meaning of truth (with a small *t*), the correspondence or ''fit'' between some part of the world and a verbal description of it.

To illustrate the important characteristics of a model, Giere uses the analogy of a map. First, like a model, the construction and use of a map has practical consequences: a roadmap, for example, permits us to navigate in unfamiliar territory (say, the streets of San Francisco). And as mentioned above, it makes little sense to speak of a map as True or False; rather, maps are more or less accurate, more or less effective in accomplishing some end (e.g., driving from airport to hotel). Second, like models, maps are genuinely representational; that is, they are maps of some*thing*; they point to, or specify, some real-life objects or events. Third, like models, maps are designed, constructed, and used for human purposes; they require a large background of social convention for their effective use. And finally, maps, like models, are incomplete; there is no such thing as a universal map complete in all details (otherwise, the map would be the territory, which it clearly is not). Rather, maps are designed to emphasize particular features at particular scales; a roadmap of San Francisco is obviously of greater use in finding one's way from the airport to hotel than a political or a geological map.

In any model there are important tradeoffs between feature selection and scale. As Giere puts it:

> It is not stretching an analogy too far to say that the selection of scale and of features to be mapped determines the *perspective* from which a particular map represents the intended terrain. Photographs taken from different locations provide more literal examples of

different perspectives on a terrain or a building. In any case, given a perspective in this sense, it is an empirical question whether a particular map represents the intended terrain. If it does we can reasonably claim a form of *realism* for the relationship between the map and the terrain mapped. I call this form of realism *perspectival realism* (SWL, pp. 214–215).

The correspondence, or mapping, of our responses to the world is central to perspectival realism. The correspondence, however, is not between response and the objective world *as it really is*, but a correspondence between a response and the world *as viewed from a perspective*, constrained by the human nervous system, by instrumentation, and by social contingencies. Correspondence relations also play a key role in Skinner's analysis of science, as described in the following section.

RELATIONS BETWEEN GIERE'S AND SKINNER'S PERSPECTIVES ON SCIENCE

Skinner's writings on science date back to the 1940s, and extended throughout his career. Indeed, his writings on science are an important part of radical behaviorism as a distinctive behavioristic philosophy. The starting point for what might be called a Skinnerian view of science is that science is behavior: observing, describing, categorizing, interpreting, reading, listening, calculating, remembering, instruction-following, problem solving, decision making, inferring, analogizing, reasoning, and so on are patterns of behavior that occur in social contexts and develop through experience with scientific communities. As such, scientific behavior is amenable to the same kind of analysis that has proven useful in understanding behavior more generally.

> The behavior of logician, mathematician, and scientist is the most difficult part of the field of human behavior and possibly the most subtle and complex phenomenon ever submitted to a logical, mathematical, or scientific analysis, but because it has not yet been well analyzed, we should not conclude that it is a different kind of field, to be approached only with a different kind of analysis. (Skinner, 1974, p. 235)

Two core concepts in Skinner's analysis of science are the *tact*, defined as a relation between a verbal response and some aspect of the world, and *rule-governed behavior*, defined as behavior in relation to verbal statements about

the world. Both involve correspondence relations: correspondence between verbal responses and some aspect of the world (tact), or correspondence between verbal description of the world and behavior in relation to that description (rule-governed behavior). Like Giere's maps and models, tacts and rule-governed activities could be said to represent some aspect of the world, but they do so in terms of specific conditions that enhance or limit stimulus control over verbal behavior. As such, Skinner's analysis of science supplements Giere's epistemological claims by providing some of the local behavioral processes by which science operates.

In technical terms, tacts are verbal responses under discriminative control of some object, event, or property of the world. Reinforcement for the tact is generalized and social (e.g., attention, praise, signs of approval), and depends on the correspondence between the verbal response and some part of the environment. For example, the response "red" is emitted in the presence of (a) stimulating conditions (e.g., an apple and someone asking, "what color is this?") and (b) a prior history of reinforcement in those circumstances (e.g., "yes, that's right"). Virtually all members of a given verbal community acquire such behavior. With greater experience in social environments, tacting repertoires become more subtle and discerning, as individuals learn to distinguish not only red from green, but rectangles from trapezoids and protons from neutrons. Although differing in complexity, the underlying processes are fundamentally similar.

With additional training in scientific communities, individuals learn an increasingly vast and technical language with increasingly fewer counterparts in the vernacular. People acquire new responses to certain parts of the world—new perspectives on the world. One way scientific communities encourage distinctive views of the world is to dispense with common everyday terms, opting instead for a technical vocabulary:

> To dispose of irrelevant controlling relations, it [the scientific community] sets up new forms of response as arbitrary replacements for the lay vocabulary—not only the special vocabulary of science but graphs, models, tables, and other ways of "representing the properties of nature"…representing an equation on Cartesian co-ordinates, constructing a three-dimen-

sional model of a complex molecule, and setting a pointer on a dial are all verbal responses supplying scientific "readers" with "texts" which often correspond with their relevant stimuli in one or more dimensional systems (Skinner, 1957, p. 419).

Tacts vary in accuracy—in the degree to which they represent, or correspond to, the world—but generalized reinforcement "makes the tact relatively independent of the momentary condition of the speaker" (Skinner, 1957, p. 90). By weakening control by deprivation and aversive stimulation, the conditions responsible for the tact arrange for a unique relation between a verbal response and a discriminative stimulus: "a given response 'specifies' a given stimulus property" (p. 83). This has important implications for science, as Skinner (1957) notes:

> Verbal behavior in which the reinforcement is thoroughly generalized, and the control of which therefore rests almost exclusively with the environment, is developed by the methods of science. The reinforcing practices of the scientific community thoroughly suppress the special interests of the speaker. This is not necessarily a sign of superior ethics in scientists; it is merely an evolved practice which has proved to be particularly valuable. It is responsible for much of the power of the scientific method (pp. 83–84).

To the extent that the special interests of the scientist can be reduced or eliminated, we are left with a relatively "pure" or "objective" tact. Although Skinner acknowledges that such conditions are rarely if ever achieved, an implication of this approach is that objectivity lies on a continuum defined by the type and degree of contact with the world. When correspondence between tact and stimulus property is high—when contingencies permit precise tacting—we call the verbal response "objective." Conversely, when the correspondence is low—when the contingencies arranged for tacting are weak or defective, or when the special interests of the speaker intrude—we call the response "subjective." Objectivity, so defined, is not a property of the world "out there," but of our verbal behavior with respect to the world. It is a product of contingencies arranged by a verbal community that places a premium on accuracy, precision, and reliability—in short, the conditions of science.

As Skinner (1974) put it:

> The verbal community of the scientist maintains special sanctions in an effort to guarantee validity and objectivity, but, again, there can be no absolute. No deduction from a rule or law can therefore be absolutely true. (p. 136)

Thus, scientific verbal behavior is no more valid or true (in some ultimate sense) than other verbal behavior, but it might be said to be more ''objective'' than other verbal responses, in the sense that it generates strong consensus regarding its use. Or, said another way, scientific verbal responses in the form of tacts are reliably evoked by a given set of circumstances, and rarely if ever under other circumstances. This is what distinguishes, in a broad sense, scientific from nonscientific verbal behavior; the former is under tighter stimulus control. For example, there is broad agreement among biochemists in the use of terms such as ''chemical structure,'' ''amino acid'' and ''phenylalanine.'' Or, said differently, these terms are evoked by specific conditions arranged in scientific communities, and rarely if ever occur outside of those contexts. Responses under such restricted stimulus control are objective, in the sense that there is broad social consensus in the use of the terms. To be sure, such consensus is provisional, subject to change with the changes in technology and in the reinforcing practices of a community. But the critical point here is that the objectivity of verbal behavior can be evaluated in relation to nonarbitrary criteria: the precision of stimulus control over verbal behavior.

This is similar to Giere's point regarding objectivity, namely that objective responses to the world are a product of an interaction between a human observer and the world, mediated both by instrumentation and by a social community. It is a perspective that is no more real than a nonscientific perspective, but it is more objective in the sense that it is shared by others in a community. Skinner's analysis of verbal behavior provides a means by which such objective behavior is established and maintained in communities, including scientific ones.

Viewed in this way, traditional distinctions between *subjective* and *objective* lose all meaning. Knowledge (including scientific knowledge) can be both subjective, in the sense of being dependent on context and individual learning histories, and objective, in the sense of being shared by a community. There is no contradiction, insofar as *subjectivity* and *objectivity* are defined on a continuum in relation to verbal practices.

Laws as Rules for Successful Action

Skinner's views on the development and evolution of science are thoroughly pragmatic, emphasizing practical consequences maintaining scientific behavior (Skinner, 1945). After Bacon and Mach, Skinner viewed science in terms of practical problem-solving repertoires with origins in the manual arts. Science is an evolved set of practices, ''rules for effective action'' (Skinner, 1974, p. 235).

Effective rules in science derive from accurate tacting repertoires—responses under precise stimulus control of objects or events in the world. Tacts are said to benefit the listener (or verbal community), in the sense that they enable others to take effective action with respect to what is said. When they do so, tacts may function as rules. For example, the statement, ''There is a snake in the closet,'' may function as a kind of rule, enabling a listener to avoid entering the closet. Similarly, the statement, ''Using 1000 Hz tones of 0.3-s duration produced the best results,'' enables other scientists to replicate a procedure. Behavior that comes under the control of such verbal descriptions is said to be rule-governed, and is critical in science, enabling others to benefit from the collective experiences of the community:

> The facts and laws of science are descriptions of the world—that is, of prevailing contingencies of reinforcement. They make it possible for a person to act more successfully than he could learn to do in one short lifetime or ever through direct exposure to many kinds of contingencies. (Skinner, 1974, p. 144)

From this perspective, facts, theories, and laws are behavioral acts—verbal statements under the control of patterns or regularities in nature. The main difference between them is generality, the range of circumstances that occasion them. A fact is more restricted generalization than a theory, and a theory is a more restricted generalization than a law. But even when a statement occurs with sufficient generality that it achieves the status

of a law (e.g., the law of gravity), it remains situated in the world of behavior, maintained by the successful behavior it enables in others.

> Scientific laws also specify or imply responses and their consequences. They are not, of course, obeyed by nature but by men who deal effectively with nature. The formula $s = \frac{1}{2} gt^2$ does not govern the behavior of falling bodies; it governs those who correctly predict the position of falling bodies at given times. (Skinner, 1974, p. 141)

Skinner (1974) reformulated scientific laws in terms of human verbal systems, as rules governing effective action:

> The objectivity which distinguishes rule-governed behavior from behavior generated by direct exposure to contingencies is furthered by tests of validity, proof, practices minimizing personal influences, and other parts of scientific method. Nevertheless, the corpus of science—the tables of constants, the graphs, the equations, the laws—have no power of their own. They exist only because of their effects on people. (1974, p. 144)

In a similar vein, Giere rejects appeals to Universal Laws that stand apart from human-created models. The Universal Scientific Law is a holdover from a classical and outmoded view of science. According to Giere, the search for Universal Laws grew out of conditions in 17th century science and theology, where Laws of Nature were thought to reflect God-given eternal verities. God eventually dropped out of science, but the notion of Universal Law was retained. It is time, Giere argues, to dispense altogether with the notion of a Scientific Law, at least in the traditional sense of the term. Laws (with a capital ''L'') are the foci of Giere's criticisms in SWL.

Giere argues that science deals not in Universal Laws, but rather in models, or restricted generalizations about some aspect of the world. Models are restricted generalizations in the sense that they are constrained by theoretical principles; principles provide rules for constructing models. Evolutionary principles, for example, dictate the type of model that is developed (e.g., it must relate variation and selection to some competitive advantage) as well as the criteria against which the model is evaluated (e.g., must have some fitness-related outcome measure). From this standpoint, models more or less accurately portray some aspect of the world across some range of circumstances. Models can be more or less effective in their correspondence with some part of the world, but they are not more or less True in some absolute sense.

The Pragmatics of Theory Choice

The key to all effective verbal systems, including science, is successful working. In science, successful working is multifaceted: refining measurement techniques, instrumentation, procedures, analytic techniques, and models. Success in the domain of model evaluation is defined by the correspondence between the model and some part of the world (the fit between a map and a territory). The fit is always partial and imperfect, of course, depending as it does on a number of factors—scope, precision, reliability, validity, to name a few—some of which are in mutual opposition. For example, the more locally precise a model is, generally the narrower its scope, and vice versa. As a result, evaluating the fit between a model and the world reflects tradeoffs between multiple criteria. Which criteria are deemed most important in turn depends on what the model is designed to accomplish.

This is where human social interests may enter the picture. A social constructivist might take this to mean that model evaluation is inherently value-laden and subjective. But the criteria according to which models are evaluated can be as objective as the contingencies permit. Testable predictions in relation to explicitly stated evaluative criteria are the mark of good scientific practices—ones in which personal and professional interests are minimized. Scientific verbal communities arrange practices that maintain a certain type of contact with the world, more specifically, a collective (shared) contact that transcends the personal idiosyncratic histories of individual speakers. As Skinner (1974) put it:

> …a scientist must behave as an individual. But if he analyzes the world around him, and if, as a result, he states facts or laws which make it possible for others to respond effectively without personal exposure to that world, then he produces something in which he himself is no longer involved. When many other scientists arrive at the same facts or laws, any personal contribution or personal participation is reduced to a minimum. (1974, pp. 144–145)

The interests and practices of the verbal community may also influence model choice—the type of model one uses to represent some aspect of the world and the evidence used to measure the fit. Such decisions are also grounded, however, in the direct experience of the scientist rather than in a world of pure reason and logical inference (as suggested by the classical Enlightenment view of science). As such, scientific judgments reflect the fallibility characteristic of human decision-making more generally. Again, this does not imply that such decisions are haphazard or irrational, only that they are continuous with other aspects of human behavior. From this perspective, it is possible to have scientific judgment (human decision-making) without Rationality (logically-deduced Ideal solutions) and realism (mapping of the real world) without Truth (a perfect model complete in detail).

COMBINING THE EMPIRICAL AND THE EPISTEMOLOGICAL: TOWARD A SCIENCE OF SCIENCE

Giere and Skinner share the assumption that science is part of the natural world, part of the world to be explained using natural-science methods. As Giere put it: ''A theory of science must itself be a *scientific* theory'' (SWL, p. 53, italics in original). Just as there are different theories of individual behavior, however, so too are there different theories of scientific behavior. Giere and Skinner offer different but complementary perspectives on what a scientific theory of science might look like.

As a scientist, Skinner's primary concerns were mainly *empirical*—the collective activities comprising a scientific repertoire and the variables of which they are a function. As a philosopher, Giere's focus is mainly *epistemological*, concerned broadly with the nature and scope of scientific knowledge. Although at times Giere discusses specific models, these are mainly to illustrate the possibility of an empirical analysis using certain kinds of models than with an analysis of any particular model. And while Giere refers to the general type of model most relevant to science as cognitive, the specific models he discusses have more in common with modern behavioral models than with the formal-computational models of classic cognitivism.

The main example of a cognitive model provided by Giere is that of parallel distributed processing (or, PDP), a family of models originating in computer science, optimized to respond to patterns of input and modified via experience. They are essentially learning-based models of adaptive behavior, and are broadly compatible with Skinnerian concepts and models (Donahoe & Palmer, 1989). Such PDP models exemplify a bottom-up approach to complex behavior, whereby cognitive complexity is assumed to arise from simpler, more elementary processes. An example offered by Giere is that of mental arithmetic. Unlike a conventional cognitive model, in which mental arithmetic would follow from an internally-executed set of rules, a PDP model would hold that doing arithmetic ''in the head'' (an internal and presumably a higher-level skill) requires a history of arithmetic ''outside the head'' (an external and lower-level skill). According to Giere, the cognition is not ''in the head'' (as traditional mentalism would hold), but in the learning history, in the system of interactions between the person and the external world.

Similarly, scientific behavior calls for responding effectively to complex arrangements of stimuli, such as graphs and other pictorial representations of the world. But even here,

> …cognition is in the interaction between the viewer and the picture, as when geologists take magnetic profiles of the sea floor…We need not imagine geologists as first forming a mental representation of the picture and then reasoning with it. They can reason directly with the external representation of the phenomenon (SP, p. 104).

In other words, the external representation of nature—the graph, the table, the model—can evoke behavior in its own right. The degree to which it does so depends, of course, on specific training. In our attempts to understand science, we should be looking not in the head of the scientist, but instead at the training experiences—the cumulative history that collectively comprises a scientific repertoire.

The skills a scientist acquires through training in specialized environments are no different in kind from skills acquired by an artist or an athlete. Just as it requires specialized training to see a magnetic profile of the

ocean floor, so too it requires specialized training to hit a 95-MPH fastball. Equipped with such skills, one might say that the geologist and the baseball player have unique perspectives on some part of the world. This does not mean, however, that the geologist and the baseball player are responding literally in different worlds; rather, their specialized skills enable them to take effective action with respect to different parts of the same world. Just as the geologist may look at the same 95-MPH fastball but is unable to hit it, the baseball player may look at the same magnetic profile map of the ocean floor but be unable to say anything meaningful about it.

Different contingencies thus give rise to different types of responses, or different perspectives on the world. As Skinner (1974) put it:

> …people see different things when they have been exposed to different contingencies of reinforcement. Like everyone else, the scientist sees green, but he also responds in other ways to the same setting…Both layman and scientist respond—in similar or different ways, depending upon the contingencies—to the features of a given setting. (pp. 79–80)

To see the world scientifically is to respond discriminatively to some parts of the world. This comes about through experience, through training in particular scientific communities and aided by instrumentation. Skinner's analysis of science is essentially an empirical analysis of these experiences. How do such skills develop? What kinds of experiences are needed to establish such skills? How are specific skills combined and integrated with other skills? How do scientific skills differ from other kinds of skills? A promising foundation for an empirical approach to science has been laid in the experimental analysis of complex behavior, which now encompasses a range of phenomena once considered beyond the purview of a behavioral account, including verbal and rule-governed behavior, relational learning, perception, categorization, problem solving, analogical and deductive reasoning, and metaphorical extension, to name just a few. A recent special issue on perception, categorization, abstraction, and relational learning in this journal (Zentall, Galizio, & Critchfield, 2002) exemplifies research and interpretation in a Skinnerian tradition. And when combined with the contextual and interactional models discussed by Giere (based on distributed and situated cognition) they provide the beginnings of an empirical science of science, part of a more general empirical science of human behavior.

In addition to more fully exploring the background skills involved in scientific repertoires, scientific behavior could be studied more directly as a subject matter in its own right. The field of science studies has to this point included mainly descriptive accounts (e.g., Latour, 1988), but laboratory research is also relevant. One could, for example, create and synthesize components of a scientific repertoire in the laboratory by simulating scientific contingencies. Subjects might be trained to observe, record, measure, and analyze complex arrangements of stimuli with consequences arranged for speed, accuracy, and consistency. They could be trained to relate different observations and facts to each other and to more general models by arranging contingencies for consistency and comprehensiveness. Social aspects of science could be studied by comparing observations made individually with those made in social contexts. These in turn could be examined as a function of contingencies arranged for correspondence with the world or with conformity to the group. Virtual social communities could be created in which research output was correlated with benefits, including the opportunity to continue playing. How would an overall scarcity of resources needed for the survival of a research program affect dissemination timing (e.g., the amount of data collected, the reliability of the results) and quality (e.g., fewer high-quality publications or many lower-quality ones)? Under what conditions would individual scientist subjects cooperate within and across virtual laboratories? When would they compete? These are just a few of the many questions that could be fruitfully explored in the laboratory, supplementing and extending descriptive studies of science. Both are needed in a comprehensive empirical analysis of scientific behavior.

SUMMARY AND CONCLUSIONS

I have attempted to show in this essay that Giere's perspectival realism and Skinner's radical behaviorism provide compatible and

complementary perspectives on the nature of science. Perhaps most fundamentally, perspectival realism and radical behaviorism share the view that science itself is amenable to scientific inquiry: scientific principles can and should be brought to bear on the process of science. As such, these perspectives join with other approaches in the emerging field of science studies in attempting to explain science as a natural process. From this perspective, science is action—the collective action of scientists in a social and historical context—and thus is part of the more general subject matter of behavior. Behavioral scientists therefore bring a unique perspective to the science of science.

The present essay suggests that, when looking toward the behavioral sciences, the field of science studies should focus more on behaviorally grounded models than on more conventional cognitive models. Traditional cognitive models have been in decline for some time now (Still & Costall, 1991), with critiques of classical cognitivism emanating from a range of disciplines, including cognitive neuroscience (Bennett & Hacker, 2003; see review by Schaal, 2005), linguistics (Andresen, 1991, 1992; Lakoff & Johnson, 1980), perception (Gibson, 1979; see review by Costall, 1984), computer science (Brooks, 1999), and developmental systems (Gottlieb, 1997; Oyama, 1985; see reviews by Schneider, 2003, and Midgley & Morris, 1992, respectively), to name just a few. Models in these areas are moving increasingly away from the formal information-processing models of traditional cognitive theory and toward historical, experience-based, and context-driven models more compatible with contemporary behaviorism. In this intellectual climate, behaviorally inspired models are undergoing resurgence, as they are applied to an increasingly wide range of topics. And with respect to science studies, in particular, models arising from a Skinnerian perspective are especially noteworthy, mainly because they are based on a sophisticated analysis of verbal behavior, including the behavior of the scientist. This is where a Skinnerian analysis supplements and extends Giere's epistemological positions; it provides a more detailed account of the local behavioral processes through which science operates.

At the same time, the epistemological questions Giere proposes enrich and extend a Skinnerian analysis. How is scientific knowl-edge generated? How are scientific claims validated? How are scientific models evaluated? Such questions provide the foundational assumptions for a science—the perspective a science takes on its subject matter. Giere's position provides a convenient entry point for a Skinnerian analysis, in part because it is so clearly articulated, and thus provides substantive points of contrast. Although Skinner's writings on science did include broader epistemological concerns, he rarely attempted to develop a philosophical stance in relation to other positions. This is perhaps one reason Skinner's views on science are underappreciated and frequently misunderstood by historians and philosophers of science. In keeping with his philosophical orientation, Giere goes to some lengths to situate his position within the intellectual landscape of his discipline, comparing and contrasting with various other philosophical viewpoints (e.g., realism, constructivism, instrumentalism, naturalism, to name a few). Reevaluating Skinner's writings on science in light of some of these philosophical positions will sharpen the contrasts between a Skinnerian analysis and more conventional views, perhaps rendering a more sympathetic reception than they have received to date. Although Skinner's writings on science date back to the 1940s and extend throughout his career, they have received little notice outside of behavior analysis.

Placing Skinner's analysis of scientific verbal behavior in a broader philosophical context may also help resolve internecine struggles in behavior analysis, such as the debate over whether behavior analysis is a form of realism or pragmatism. Viewed in light of an empirical analysis of verbal behavior, such categorical distinctions fade. Scientific practices develop and evolve through effective action—a pragmatic view. At the same time, however, effective practices are often ones that assume a world that exists apart from our responses to it—a realist view. To be sure, the world as we construe it is in part molded by our responses to it. But this makes the world—and our responses to the world—no less real. It simply puts our understanding of the world into the same physical domain as the world itself. Thus, within a modern view of realism, one based on an empirical analysis of verbal behavior, pragmatism has a home. Once the illusions of classical realism are shattered, a pragmati-

cally-driven realism, grounded in the practical everyday world of behavior, is where a modern empirical science of science begins.

Perhaps Skinner's most enduring contribution to the science of science was his insistence that even epistemological questions fall within the scope of an empirical analysis of verbal behavior. Epistemological questions are questions about verbal behavior—the kinds of questions that are asked, the kinds of observations and experiments that are done, the kinds of evidence that is deemed appropriate, and so on. Asking (and answering) such questions are behavioral acts related to history, context, and experience, and constitute part of the empirical analysis of science. Thus, apart from the particular content of a discipline—be it subatomic physics, molecular biology, computer science, or behavior analysis—the methods, concepts, and models of a science—its perspective on the subject matter—exist in the realm of behavior, and are thus subsumed within the analysis. As we gain new insights into the process of science, we will learn more about how to produce better science—not better in some absolute sense, but better in the practical sense of solving problems and creating new technologies. Ultimately this is what a science of science is all about.

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