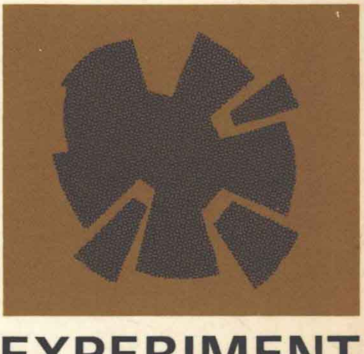

THE PSYCHOLOGY EXPERIMENT

AN INTRODUCTION TO THE SCIENTIFIC METHOD

BARRY F. ANDERSON

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PREFACE

This book helps the reader to understand the scientific method by telling him how to conduct an experiment; that is (except for Chapter II, which is somewhat more formal), the scientific method is presented from the point of view of the person who uses it. When the reader finishes the book, he should be able to carry out experiments on his own—experiments that are sound, efficient, and complex enough to be interesting.

The experiment has been chosen to represent the scientific method because it can be regarded as both an idealization and a miniaturization of the scientific method. The experiment is the unit that most fully embodies the principles of the scientific method; it is also the smallest unit that embodies all of these principles and displays their over-all logic.

This book deals with many topics that are ordinarily introduced only in advanced treatments of scientific experimentation. This enlarged scope has been achieved, in part, because points not essential to a working understanding of the experiment are omitted and, in part, because intuitive explanations are substituted for rigorous mathematical proofs. Mathematics is kept to a bare minimum; the logic of statistical inference, for example, is developed in terms of simply counting outcomes. At the same time, an attempt has been made to provide intuitively reasonable answers to all questions which are raised in the book and, thus, to make it as nearly self-contained as possible.

This is a book on the scientific method as applied to psychology, not a book on the methods of psychology. Psychology is just another science, and its procedural rules are essentially the same as those of physics, chemistry, biology, and sociology; this similarity of approach is what makes them all sciences. Specialized techniques that are peculiar to psychology have been avoided in favor of methods common to the various sciences. The book is psychological in one significant respect, however; general problems of scientific procedure are emphasized in proportion to their importance in psychology. Examples are drawn both from everyday life and from the psychology laboratory.

The organization of the book is wheel-like. Chapter II, "The Scientific Method," describes the wheel; Chapter III, "The Experiment," presents the hub; and the remaining chapters present topics which radiate from, and are directly related to, the experiment: descriptive statistics, statistical inference, improving the efficiency of a design, adding to the complexity of a design, writing up a research paper, and getting ideas for experiments. An attempt has been made to relate the parts to the whole—to present research tactics in the broader context of research strategy and ultimate goals. In describing the scientist's approach, attention is kept not only on the logic which justifies his procedure but on his reasons for doing what he does.

The book is probably best read straight through, with two exceptions. Chapter II, "The Scientific Method," should really be read both before and after the rest of the book. Chapter X, "The Idea behind the Experiment," can be read any time; if, however, the reader plans to prepare an experiment while he is reading the book, it would be best to read Chapter X after Chapter II.

It is true, though a commonplace, that a book is the work of many people. I would like to thank all those who have, in one way or another, helped in the preparation of this book, and I would like to express a special debt of gratitude to Robert Welch and William Johnson, who brought many errors and points of obscurity to my attention, and to Ray Hyman, Burton G. Andreas, John F. Brackmann, Jr., and Daryl Bem, whose suggestions were particularly helpful in improving the quality of the book and of my understanding.

Barry Anderson

CONTENTS

I INTRODUCTION

Science is a body of knowledge, a social institution, or a method for acquiring knowledge, according to one's point of view. Science as a body of knowledge is treated in books on physics, chemistry, biology, psychology, sociology, and the other sciences. Science as a social institution is a topic of sociology, anthropology, and history. The concern of this book is with science as a method.

There are at least two reasons for inquiring about the scientific method. One is that it is important to understand any influence which has affected, as markedly as science has, both the shape of the world in which man lives and man's conception of his place in the world. Materially, science has, of course, added to the furnishings of the world such things as gasoline, electricity, steel, plastic, penicillin, vaccines, the automobile, the airplane, photography, radio, television, and the high-speed digital computer. In the realm of ideas, science has dislodged man from his privileged place at the center of the universe (Copernicus), deprived him of much of his biological uniqueness (Darwin), and brought his rationality into serious question (Freud). At the same time, however, by ridding the world of many ghosts and by greatly extending the range of man's experience and power, it seems that science has begun to establish a new and sounder base for human dignity. Certainly, science has had, and will continue to have, a profound effect on man's life.

When one looks back into history to the time when science showed little more promise than philosophy, the pseudosciences, folk wisdom, and magic, one wonders—much as one sometimes does in looking at a childhood picture of a great man—what was different about science that enabled it to go so much farther than its contemporaries. What were scientists doing that philosophers, astrologers, and soothsayers were not doing? Why did scientists accomplish so much more than those following other ways to knowledge? The educated man in modern society should have an answer to such questions.

A second reason for studying the scientific method is that we are all scientists in a common-sense way, and a knowledge of the methods of the formal discipline of science might help us in our everyday thinking. We all strive to build up a working knowledge of the world which will enable us to get about in it successfully. We learn what belongs in this category and what belongs in that, what to seek and what to avoid, where certain things are located, how to make certain things happen and how to keep others from happening. We develop "theories" about the world, represented in a patchwork of likes and dislikes, proverbs, rules of thumb, analogies, and prejudices. These "theories" serve us more or less well, but the more we can improve upon them, the more effectively we should be able to conduct our lives; and it is not unreasonable to expect that a familiarity with the scientific method, the most successful method for learning about the world, might have a beneficial effect on our ability to understand the world we find ourselves in.

Indeed, the scientific method—along with exposition, logic, and mathematics—may be regarded as an extension and refinement of everyday thinking. All of these disciplines are concerned, not with facts, but with ways of dealing with facts; and books in these areas are all in a sense "how to" books on thinking. From this point of view, the present volume is a book about the improvement of one's day-to-day method of acquiring knowledge about the world—as well as a book about a particular method for acquiring knowledge about the world which has been developed over several centuries by some of history's finest minds, and which has proved to be singularly effective.

II THE SCIENTIFIC METHOD

What is the scientific method? If you went out and asked a dozen scientists this question, their answers probably would not all be the same. One frequent response might run, "You can't answer that question. There isn't one scientific method; there are many. The naturalist just sits and looks at baboons. The theoretician doesn't look at anything; he juggles formulas. And the experimental scientist does something in between." Another common response would be, "There is no one method common to all sciences. Anthropology, with its anecdotal description and armchair speculation, can't be placed in the same class with biophysics and its highly refined procedures of observation and theory construction."

However, if you forced your interviewees to attempt a definition of the scientific method, you would find some common themes running through their answers. All would say something about observation, and probably something about careful observation or controlled observation. And all would say something about subjecting theories to empirical test. It is these common themes with which we shall be concerned in this chapter.

A Definition of the Scientific Method

What, then, is the scientific method? To begin with, it is surely a method of some sort, and, as such, it may be very broadly characterized as a particular set of rules for achieving certain goals. It can be distinguished from other methods—methods for learning to type, methods for acting, methods for raising children—both by its goals and by its rules.

The ultimate goal of science is to arrive at an understanding of the world. To understand a thing fully is to know both what it is like (description) and why it is the way it is (explanation). Description is the empirical goal of science; explanation, the theoretical goal. Our provisional definition of the scientific method may thus be narrowed to the statement that the scientific method is a particular set of rules for describing and explaining phenomena.

This definition must be narrowed still further, however; for to some extent common sense, the pseudosciences, and philosophy share these goals with science. These approaches differ from science primarily in the rules they follow. There are six rules which, taken together, seem to characterize the scientific method uniquely and thus distinguish it from other approaches to understanding the world. *The scientific method is here defined as the following set of rules for describing and explaining phenomena: operational definition, generality, controlled observation, repeated observations, confirmation, and consistency.*

The remainder of this chapter falls naturally into two parts. The first deals with the goals of science, and the second deals with the rules which science follows in pursuing these goals.

B The Goals of Science

In describing events, the scientist merely reports what he sees. He may report, for example, that in the United States the average IQ of Negroes is lower than the average IQ of whites. In explaining events, he subsumes his description under some general principle or principles which are known, or presumed, to operate in other situations as well. The Negro-white difference in IQ might be accounted for in terms of principles of heredity, or it might be accounted for in terms of principles of learning. The same fact—in this case, the fact that American Negroes' IQ's are lower than those of whites—can have quite different implications, both for practical action and for further research, depending on the theoretical explanation accepted.

Description is more important in the early stages of research, and explanation is more important later. One does not worry about explanation until he has facts to explain. In the very new area of dream research, for example, description is still the principal concern. Researchers in this area have found that dreaming occurs about four times a night, that dream periods are characterized by rapid eye movements and brain waves similar to those of the waking state, that dreams are usually in color, and that the speed of events in dreams is about the same as that of events in the real world of waking life. All of these are simply descriptive statements; none proposes an explanation.

Once we have a rough description of the facts, explanations are proposed and tested. Consider, for example, the following description of the so-called moon illusion: The moon appears larger when on the horizon than when at the zenith. The description is simple; explanation, however, has proved far more difficult. It has taken over 1,800 years to get from the correct description of the moon illusion to the correct explanation. Three explanations have been proposed: the diffusion theory, the angle-of-regard theory, and the apparent-distance theory.

The diffusion theory asserts that the *physical image* of the horizon moon is larger because the light from the horizon moon is scattered more widely on its longer passage through the atmosphere. This theory has been disproved by the finding that photographs of the zenith and horizon moons are identical in size. (Apparently the effect depends upon psychological factors, which, of course, are not present in the camera.)

According to the angle-of-regard theory, the zenith moon looks smaller because the observer must turn his eyes upward in their sockets to look at it. (The exact reasoning is involved and need not concern us.) This theory has been disproved by the finding that the illusion does not appear when the zenith moon is viewed first with the eyes turned upward and then with the head tilted back, so that the moon is seen with eyes looking straight ahead.

The apparent-distance theory asserts that the horizon moon appears to be farther away than the zenith moon because of the terrain over which it is seen; because the horizon moon appears to be farther away, we see it as larger. (Again, the subtleties of the argument need not concern us.) This theory is supported by the finding that the illusion disappears when the horizon moon is viewed through a hole in a piece of cardboard, so that the terrain cannot be seen. It is further supported by the finding that the greater the apparent distance along the terrain, the greater the effect. For example, when the horizon moon appears over the mountains at the distant end of a vast prairie, it seems larger than when it appears over the nearby roof of a neighbor's house.

From the dream-research and moon-illusion examples, it can be seen that description remains important throughout the development of science. Description is usually the first step in understanding phenomena. In the later stages, as the scientist begins to develop theoretical explanations of his observations, description is used more and more frequently for the purpose of testing theories. The scientist spends less time "just looking" and more time "looking for something." Theory tells the scientist where to look in order to get the most out of his observations. Who would have thought to observe the moon through a hole in a piece of cardboard without a theory to guide him? Who would have thought to drop two cannonballs from the Tower of Pisa without a theory to guide him? Who would have thought to attempt to break up the uranium nucleus without a theory to guide him? Once past its infancy, science constantly works back and forth between description and explanation. Observations suggest a theory; the theory suggests that certain other observations be made to test it; the new observations modify the theory; and the modified theory suggests still other observations.

1 Description

Description is the process of arriving at valid descriptive statements. Two kinds of descriptive statement will be considered, *state descriptions* and *process descriptions.* There are two things one can say about an object or class of objects. One can tell what it is like at some given point in time, or one can tell how it works. The statement of what an object is like at some given point in time is a state description; it is like a still picture. The statement of how an object works is a process description; it is like a motion picture. Consider, for example, the task of describing a very familiar object, a house.

In "taking a still picture" of a house, one might list the numbers of bedrooms, bathrooms, and closets. One might also indicate which rooms have windows, thermostats, and heaters, which have lights and light switches, and how many of these are in each room. Such a description, which covers the present state of the house, is an important aspect of the total description, but it misses some very important facts. It does not tell you how the house works—that is, what its causal structure is. For this, a "motion picture" is needed.

In "taking a motion picture," one *changes* things and observes what *changes* with them. One might flick the light switches up and down and notice that the lights go on and off; or open the windows for a while and then close them and notice that the thermostat reading first drops and then rises; or change the setting on the thermostat and notice that the heater goes on and off. Process description permits one to group events into causal chains—to speak, for example, of a heating system, a lighting system, a plumbing system, and a structural system.

A state description, in its simplest form, specifies a value on a variable. The house is located on the color variable by the statement "It is white," on the size variable by the statement "It has ten rooms," and on the number-of-thermostats variable by the statement "It has three thermostats." Similarly, one might describe a person by locating him on a height variable, a mental-ability variable, a sex variable, and an age variable. State descriptions take the general form:

For (object or class) X, variable A has value a_1.

A process description, in its simplest form, specifies the causal relationship between two variables. The light switches control the lights; the thermostats control the heaters. For a normal child, a change in age produces an increase in height; a change in age produces an increase in mental ability; but a change in age does not produce a change in sex. Process descriptions take the general form:

For (object or class) X, when variable A is changed, variable B also changes.

In science a class of objects, rather than a single object, generally is described. If, in the preceding example, a class of houses had been observed, the descriptive statements might begin "For houses in this district" or "For houses built by Bergstrom Brothers" or "For houses in the United States." In other respects, these statements would be identical in form to the descriptions of the single house.

The terms "value," "variable," and "relationship" have been used without definition. Let us consider more carefully the meanings of these terms, since they will be used repeatedly throughout the book.

a Variables

To understand what a variable is, we must begin with properties. *A property is something which characterizes some things but not others.* Red is a property. It is characteristic of cherry lifesavers, lipstick, and cardinals but not of coal, snow, or helium. Some order can be imposed on the vast array of properties in the world when these properties are treated as variables. *A variable is a set of mutually exclusive properties.* Blonde and brunette, male and female, and thin and fat are all properties; but, although there are six properties here, they represent values on only three different variables: hair color, sex, and body build. Hair color is a variable because blonde and brunette are mutually exclusive properties; no person can conceivably be both predominantly blonde and predominantly brunette. Sex and body build are variables for the same reason; no person can have two sexes or two dominant body builds. Different properties on the same variable are commonly referred to as *values* on that variable; thus, blonde and brunette are values on the hair-color variable.

b Relationships between variables

A relationship exists between two variables when knowledge of an object's value on one variable enables you to predict its value on the other more accurately than you could without such knowledge. A relationship exists between high school grade-point average (GPA) and college GPA, because you can do a better job of predicting a person's college GPA when you know his high school GPA than when you do not. When knowledge of one variable enables you to predict the other perfectly, a perfect relationship between the variables is said to exist. When knowledge of one variable does not enable you to predict the other any more accurately than you could without such knowledge, no relationship is said to exist. Usually, when a relationship does exist, it is of moderate degree; knowledge of one variable improves your ability to predict the other but does not make prediction perfect.

A very important distinction exists between causal relationships and noncausal relationships. *A causal relationship is said to exist between two variables when a change in one produces a change in the other.* Flicking the light switch up and down turns the light on and off. Causal relationships are unidirectional. Turning the light on and off (for example, by screwing the bulb in and out) does *not* cause the light switch to snap up and down. One variable is always the cause, the other always the effect, and the direction of the relationship is never reversed.

A *noncausal relationship* is said to exist between two variables when a relationship exists between them but when a change in one does not produce a change in the other. An example of a noncausal relationship is the relationship between the number of mules and the number of Ph.D.s in a state. It is a fact that states with the greatest numbers of mules have the fewest Ph.D.s, and vice versa. Does this fact mean that number of mules and number of Ph.D.s are causally related? Likely not; if you flood a state with mules, you probably will not scare out any Ph.D.s, and vice versa. The causal link is most likely indirect, by way of some third variable that is causally related both to number of mules and to number of Ph.D.s —for example, a variable like degree of urbanization. Urban states undoubtedly have a greater number of attractive positions for Ph.D.s, and rural states have greater use for mules.

Relationships have a place in both process and state description, but their interpretations in the two cases are somewhat different. In process description, causal relationships indicate causal connections between variables assumed to be distinct. In state description, noncausal relationships are interpreted as reflecting the degree to which two variables are really measures of the same thing.