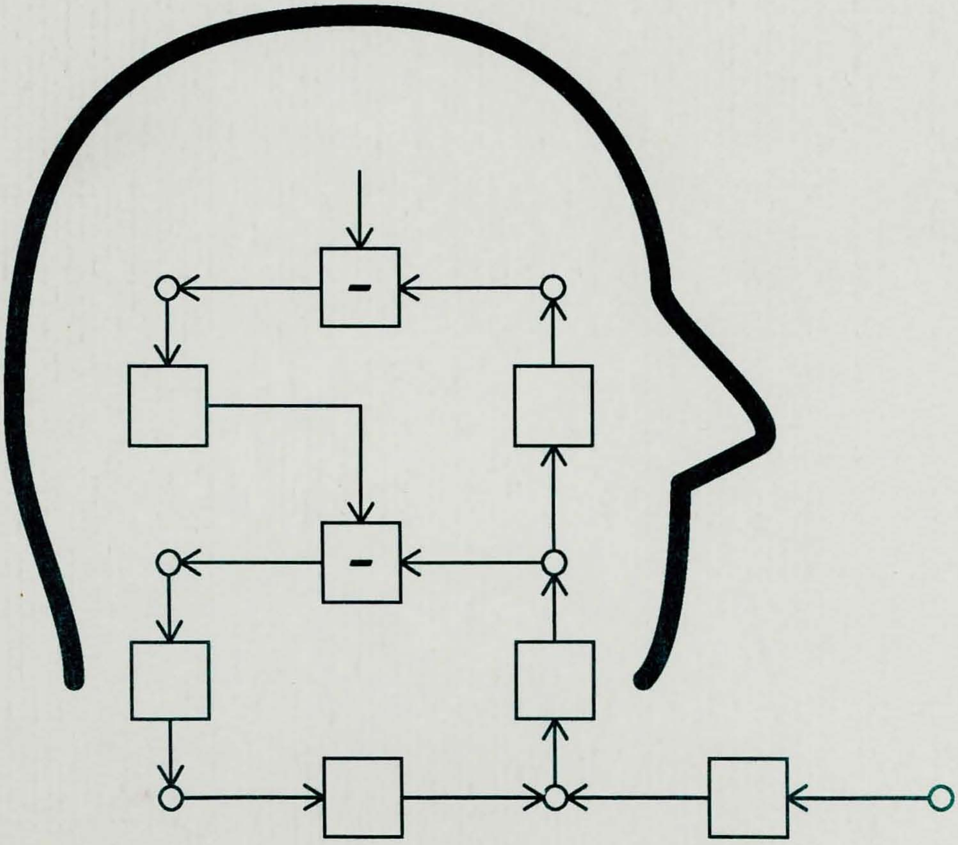
Introduction to Modern Psychology

The Control-Theory View

Edited by
Richard J. Robertson
and
William T. Powers



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This is the first textbook based on the control-theory approach to the science of psychology. It reviews, and makes theoretical reinterpretations of, many facts found by researchers working within the framework of older traditions in psychology. The basic control-theory model for *organismic behavior as the control of perception via hierarchically arranged negative-feedback loops* is detailed early on, providing a foundation for later chapters on learning, development, perception, personality, social psychology, psychotherapy, and other topics.

Robertson, Powers, and their colleagues provide what is lacking in other general psychology texts: a unified approach to the entire field, from laboratory studies of animal behavior, through ethology and studies of human social behavior, to clinical work. This volume is suitable as the primary text for introductory college-level psychology courses, as supplementary reading for advanced courses in the behavioral sciences, and for independent study. Its treatment of control-theory ideas is completely self-contained, but ample references are provided for those who want to learn more.

Richard J. Robertson is a professor of psychology at Northeastern Illinois University, Chicago. William T. Powers, the originator of the control-theory model, is an independent investigator in Northbrook, Illinois. Other contributors are David M. Goldstein, a clinical psychologist and consultant to various hospitals in New Jersey; Richard S. Marken, a human-factors engineer with The Aerospace Corporation, Los Angeles; and Frans X. Plooij, a developmental psychobiologist at the Pedological Institute of the City of Amsterdam, The Netherlands.

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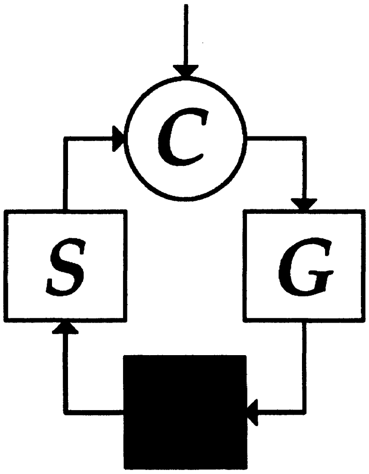
Introduction to Modern Psychology

About CSG

The Control Systems Group, Inc. (CSG) is a membership organization supporting the understanding of cybernetic control systems in organisms and their environments: *living control systems.* Academicians, clinicians, and other professionals in several disciplines, including biology, psychology, sociology, social work, economics, education, engineering, and philosophy, are members of CSG. Annual meetings of the Group have been held each fall since 1985. CSG publications include a newsletter and a series of books; a journal is being planned. For more information about CSG, write to The Control Systems Group, Inc., Business Office, 1138 Whitfield Rd., Northbrook, IL 60062.

The CSG logo, designed by Mary A. Powers and Gregory Williams, shows the generic structure of cybernetic control systems. A comparator (C) computes the difference between a reference signal (represented by the arrow coming from above) and the output signal from Sensory (*S*) computation. The resulting difference signal is the input to the Gain generator (*G*). Disturbances (represented by the black box) alter the Gain generator output on the way to Sensory computation, where the negative-feedback loop is closed.



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Preface

When one tells a story about a single experience which changed the direction of his or her life, it is usually in reference to a religious conversion. My first department chairman, Vin Rosenthal, has from time to time suggested a parallel with my relation to control-theory psychology. In fact, he has opined occasionally that I am a displaced missionary—"preaching" control-theory psychology to an often indifferent academic world. Perhaps he has had a point.

It is certainly true that on one particular Thursday afternoon in 1957 (I forget the month, probably October), I had an experience which, as far as I am concerned, really did change the course of my life. In it, I found an approach to psychology which has felt worth pursuing ever since. Three fellows came to present a lecture at one of the open seminars held on Thursday afternoons at the University of Chicago Counseling Center, where I interned. I had been a somewhat indifferent graduate student in my basic studies up to this point. Not that I was uninterested in them. I have always especially revered the core topics in psychology—learning theory and developmental theory—in the opinion that there is nothing as practical as good theory. However, I had not been satisfied with the views of these subjects which I had been offered up to that point, and consequently I had been unable to invest much energy in mastering the explanations of behavior put forth in them.

That 1957 lecture "opened my eyes" and filled me with an excitement about the underlying nature of human behavior which has never left. The material presented was subsequently published as Powers, Clark, and McFarland (1960a and 1960b), and, of course, was the initial statement of the views presented in this volume.

Acknowledgments

Many people have contributed to the motivation and the ideas in this book. First, I have to thank Bill Powers, Bob Clark, and Bob McFarland for introducing me to their view, and for their perserverance in donating the time and energy required to launch and keep the feedback theory alive until it could gain an audience. I also want to acknowledge their generosity over many years in many personal ways, including the opportunity Bob McFarland provided me, through an appointment at VA Research Hospital in Chicago, to learn the theory from him and Bob Clark.

Thanks are due Bill for the many hours he has given to helping my students, and those of other academics in the Control Systems Group, understand the control-theory approach, and for showing us how to implement it with workable research.

Two former students of mine deserve special mention: Pat Alfano, who has come back repeatedly to gain increasing mastery of the theory (cf. Robertson and Alfano, 1985), helped to explain it to other students, and contributed to this book by proofreading and offering editorial suggestions for many of the chapters; and Mike Mermel, who developed many of the computer programs which I have used in research and demonstrations in my early attempts to teach undergraduates control-theory psychology. Many other students have contributed in ways too numerous to mention.

Thanks also are due the series of chairpersons in my department at Northeastern Illinois University, Vin Rosenthal, Vic Dufour, Bob McFarland, and Peggy Condon, and my colleagues in the department, for their support in allowing me the freedom to deliver the control-theory approach in some new courses when it was untried and unheard of, and also to the members of the Control Systems Group who have been active in formulating and communicating the basic ideas, most notably Tom Bourbon, Rick Marken, and Wayne Hershberger, but including many others whose work is identifiable in this volume's references.

I also feel an intellectual indebtedness to Thomas Kuhn for his seminal concept of the scientific revolution. I truly can say that I have drawn support from his description of the processes of crisis, resistance, and eventual paradigm shift at various times when I felt discouraged and considered abandoning what seemed a hopeless investment of energy.

Finally, many thanks are due my wife, Vivian, for her patience and support as I spent hours and hours on control-theory projects which might otherwise have gone into family recreation or enhancing the family income, and Mary Powers, for her unflagging support of Bill's efforts, her own contributions to the development of control-theory thinking in psychology, and her many practical contributions to the organization and conduct of the Control Systems Group and its annual meetings.

About the Authors

David M. Goldstein is a clinical psychologist, a consultant to various hospitals and training programs, and a pioneer in the development of a truly workable research- and theory-based approach to clinical psychology.

Richard S. Marken was for 12 years a professor of psychology at Augsburg College. He is now a human-factors engineer with The Aerospace Corporation.

Frans X. Plooij is a developmental psychobiologist heading the Department of R & D, Pedological Institute of the City of Amsterdam (Institute of Child Studies). With his wife, anthropologist Hetty van de Rijt-Plooij, he studied infant chimpanzee development at the Gombe Research Center, Africa, and described the evidence of step-by-step development through successive control-system levels consonant with Powers' model, later paralleling these observations on human infants.

William T. Powers is associate editor of this volume and originator of the model presented here. He has authored many articles (see Powers, 1989) and has invented many demonstrations furthering the development of that model.

Richard J. Robertson is editor of this book and professor of psychology at Northeastern Illinois University.

Each author's contributions are his own views. While the editors have exercised a certain amount of stylistic control to slant the exposition toward the intelligent layman and the university undergraduate, no attempt was made to force the various chapters into total harmony or. consistency, other than that which has come about naturally from the common position provided by the basic model.

Richard J. Robertson
Northeastern Illinois University
Chicago, Illinois
January 1990

Part 1
Psychology and Science

Chapter 1
A Science of Psychology

1.1 Introduction

This book is a textbook on the new, control-theory approach to the science of psychology and also a general psychology text based upon the control-system model. In its function as an introductory general psychology text it reviews, and frequently makes theoretical reinterpretations of, many of the facts found by researchers working within the framework of the older traditions in psychology.

In keeping with the usual mold of general psychology texts, we begin with a discussion of the nature of science and where psychology fits into that picture. Our view of the history of science has been greatly influenced by Thomas Kuhn's (1962, 1970) theory of how science has evolved through history, especially his conception that scientific progress consists of periodic revolutions in thought called "paradigm shifts."

This introductory text was begun owing partly to Kuhn's suggestion that new paradigms in science tend to be accepted first among young scholars who have a sense (however dim) that current theories are no longer adequate to extend the frontiers of their science. The present situation in psychology appears to be just such a situation. It hinges on a problem with the meaning of *control* in behavior.

The traditional Behaviorist position is that behavior is controlled by the environment. For example, Bandura (1978) quotes B. F. Skinner (1971), the leading Behaviorist, "A person does not act upon the world, the world acts upon him." Laymen typically use the term in just the opposite way. For example, a book titled *The Writer's Control of Tone* (White, 1970), explains how an author can foster the mood he or she desires in a reader by choice of writing style, implying that "control" means bringing about the condition you desire. In other words, we try to make our environment match our specifications; when we do, that is controlling it.

Laymen link control with one's *intentions*, or purposes, as when a reporter writes, "The driver lost control of his car," meaning that the driver failed to steer it where he intended. This view does, indeed, represent a paradigm shift in the basic assumptions underlying traditional psychology. The philosophy of science which underlies Behaviorism ruled out the concept of *intention* as being unscientific, because it seems to imply that behavior could be "stimulated" from the future. That would be an impossible scientific concept.

This is a mistaken conclusion. It is based upon the assumption that our actions are "stimulated" by forces in our environment. We shall show below that a perfectly realistic mechanism of *intention* can not only be clearly defined, but working models are currently functioning every day. We do not accept the assumption that behavior is caused by forces outside the individual. Rather, forces outside the individual are disturbances which must be controlled as the person acts continually to realize his or her intentions.

Science is, in the broadest sense, an organized search for truth, knowledge, or information about nature, or reality. The science of psychology deals with that aspect of nature involved in behavior. There is beginning to be a serious debate over whether the traditional Behaviorist view or the layman's common-sense view is closer to the truth. At issue here is whether we assume that action originates in the person or the environment. As we contrast the conception of human nature underlying the control-theory model with that of current psychological conceptions, it will become clear that to assume that action originates in the individual does represent a fundamental revolution in psychology as a whole.

There is always an interplay between how you go about science and the paradigm within which you conduct it. That comes out immediately when we consider the aim of a science of psychology. Current textbooks of general psychology commonly state that the aim of a science of psychology is "prediction and control of behavior." Here, right at the outset, there is a conflict between the old and the new paradigms. The new model of human nature implies that, under many circumstances, human behavior will be predictably unpredictable. (Why this is will be shown below.)

A related implication of the new model of human nature is that attempts to control behavior from *outside* the organism will result in resistance and conflict, not harmony and efficiency.

Yet there is a sense in which we sympathize with what we believe was the intent behind stating "prediction and control" as the goal of psychology. It is the goal of any physical science. We humans have a long history of contending with the forces of nature for greater security and happiness. It is meaningful to want to gain the ability to predict and control such potentially destructive forces of nature as the weather, movements of the land and water, and similar aspects of reality.

Such an intention to control nature is implicit in the model of the organism as an *environment control system*. However, we shall show that the development of psychology as an enterprise aimed at imitating this aspect of the physical sciences would imply trying to control control systems as if they were like inanimate nature. When psychologists tried to develop a science on this basis, it resulted in an impasse, creating the need for a wholly different paradigm.

How do we state this new paradigm? By exactly reversing Skinner's position (above) that the world acts upon the organism. *The organism is an environment control system,* not a reflex-machine. This view has been increasingly accepted among biologists (see Reiner, 1975; Bayliss, 1966; Kalmus, 1966), but it has yet to gain wide recognition among psychologists.

Many everyday observations of behavior seem explainable equally well in terms of both the old and the new paradigms. For example, if I walk out of my front door on a cold day and then turn around and go back in to put on a coat, this action could be seen either as an example of the environment controlling me—causing a change in my action—or me controlling the environment—keeping the air temperature right around my body under as tight control as possible. While the facts of this instance remain exactly the same, the two opposite ways of *explaining* the event embody the paradigms which are in conflict.

The control-system model is built upon the theory of "negative-feedback control systems." A desired state of affairs is maintained against external disturbances by (1) comparing a *feedback signal* (reflecting the current state of the condition under control) with a *reference signal* (the *desired* state); (2) representing the mismatch by an *error signal*; (3) acting upon the environment so as to erase the error signal—thus reestablishing the match between current and desired conditions.

A familiar example is the temperature control system in the home. If the temperature departs from the desired condition (specified by the setting you give the thermostat), then the heating or cooling apparatus is triggered into action to eliminate the mismatch. The control-theory paradigm developed out of the realization that this is how living organisms act upon their environments. (In fact, as Powers (1978) pointed out, we humans invented electromechanical control systems to imitate aspects of our behavior which earlier machines could not perform.) Intentions are the desired (or reference) states that living organisms act to maintain under control. *Intentions* are *reference signals*.

When the father of Cybernetics, Norbert Wiener (1948), suggested that negative-feedback control systems duplicate functions of living organisms, there were at first a multitude of objections: this would mean living organisms are entirely homeostatic and could never change; this could explain physiological functioning, but not "higher" cognitive or personality functioning; you couldn't do "real science" in psychology if you didn't start with the outside environment. Each of these objections now has been disproven, and we shall describe how in detail below.

Although many actions can be explained in terms of either the old or the new paradigms (as shown above), not all examples of behavior can be equally well explained under each paradigm. For example, Marken (1986) and Holst (1954) provide research results (described later in this book) which contradict the traditional model of behavior as a *re*acting system. Their results conform easily with control-system theory, but not with traditional Behaviorist theory. Furthermore, Marken's research illustrates a model-testing, rather than a statistical approach, to finding new facts.

The first of the favorite techniques of "scientific" psychology to fall in the new approach is the statistical approach to theory building. In physics, a "causal connection" ordinarily requires correlations of the order of 0.99. In psychology, this sort of rigor has up to now been regarded as unattainable (but see Marken, 1986), supposedly because too many influences interact in any one sample of "behavior."[1]

We suggest that there is a different reason why the "principles ofbehavior" proposed in many traditional psychological studies only show up as slight, statistically measured tendencies. That is that most of the "principles" of behavior proposed up to now are not real principles, but instead are names for generalizations. See Mary Midgley's (1978) comments on Behaviorism in *Beast and Man: The Roots of Human Nature*: "What is scientific is *not what looks like* physical science, but what *is* like it—in the sense of using the right methods for what it is trying to do."

What we see as the results of the paradigm revolution in psychology—from an environment-controlled to an environment-controlling view of organisms—should become clear in the rest of this chapter.

1.2 Paradigms in Science and the Nature of Scientific Revolutions

Thomas Kuhn (1962, 1970) introduced an extremely creative idea regarding the history of scientific thinking in his book *The Structure of Scientific Revolu-*

tions. In it, he argued persuasively that science has not progressed in a straight line down through history, steadily accumulating more and more "true" facts. He described, instead, a process of evolution in which there are periodic crises followed by revolutions in which new ways of understanding nature emerge. He termed these revolutions in thinking "paradigm shifts." He indicated that they occur when scholars in a given field begin to become dissatisfied with the explanatory abilities of their current views.

A paradigm is, most literally, a pattern or mold which forms the basis upon which something is constructed. A classic example of a paradigm shift in science is the one which occurred during the 15th to 17th centuries, as scholars changed their belief that the sun revolves around the earth to the new view that the earth and other planets are satellites revolving around the sun.

Kuhn argued that paradigm shifts in science don't simply mean new theories; they mean new *kinds* of theories. The basic assumptions upon which theories are built are overturned, and the same old reality suddenly gains new implications. For example, as long as the world was thought to be a flat plate lying on the floor of the universe, you could get to China from Europe only by going east. But when people accepted the idea that the earth might be a round ball floating in space, it became possible for Columbus to imagine getting to China by going west.

Paradigm shifts in science don't necessarily mean that accepted facts are wrong. The stars at night look just the same, whether you see them as lights hanging in a dome or as incredibly distant fiery bodies. The distances between them stay the same on the telescope lens. Sailors still can use them equally well to estimate where they are on the oceans. But many new discoveries became possible, and many small measurement errors cleared up, only when the Copernican model of astronomy gained acceptance.

A similar situation holds true with other paradigm shifts in science. New ways of explaining facts often lead to perceiving new relationships between them, and the significance of many facts undergoes change. Some points previously thought trivial take on new importance, and others, previously regarded as weighty, suddenly become superficial.

1.3 The Need for a New Paradigm in Psychology

1.3.1 Growing Dissatisfaction with the Current Paradigm

Many psychologists today believe that the science of psychology is in need of, or is already in the first stages of, a paradigm shift. For example, A. C. Elms (1975), writing on "the crisis of confidence in social psychology," stated, "During the past decade... many social psychologists appear to have lost not only their enthusiasm, but also their sense of direction and their faith in the discipline's future." Quoting Leonard Berkowitz, whom he called a leader in the field, Elms continued, "'Social psychology is now in a "crisis stage" in the sense that Kuhn used the term in his book, *The Structure of Scientific Revolutions*....'" Elms went on to quote Brewster Smith (1973), another leader in the field of personality and social psychology: "'Our best scientists are floundering in the search for a viable paradigm...'" (p. 464).

Julian Rappaport (1977), a clinical and personality psychologist who evolved into a position of leadership in the new field of community psychology, saw that field as in a state of crisis, also for want of a new paradigm.

Alan Boneau, writing under the title "Paradigm Regained?" (1974), referred to Kuhn's work in proposing that a paradigm shift is occurring, or needs to occur, in psychology. He said, "What is needed is a schema to utilize [the recent advances in technical sophistication of psychologists] as basic building blocks of a coherent structure" (p. 278). His candidate was the then-new information-processing approach.

The fundamental issue, as Boneau saw it, was this: "While behavioristic approaches tend to imply that behavior is under external control, as expressed in the widespread use of the term *stimulus control*, the decision-theory/information-processing approach, on the other hand, seems to imply that behavior is determined primarily by events within the organism." His solution was to attempt building a bridge between information processing and operant conditioning schemes. We do not advocate that solution, but we heartily endorse his perception that behavior is controlled by the organism rather than the environment.

1.3.2 Control Theory: Paradigm Shift in Psychology

The shift to which we refer is a shift from a stimulus-response paradigm to a feedback-control paradigm as the basic building block in psychological explanations. The stimulus-response paradigm really goes back to Descartes (1637/1972), who originated the concept of "reflex" (although that term appears to have been coined later). Descartes generally is credited with the suggestion that behavior could be studied scientifically, while Wilhelm Wundt is considered the father of psychology as a separate science.

Because Descartes believed that "mind" is the function of a non-physical soul, and hence not subject to the laws of physics, his views injected the now infamous body/mind split into the study of the human organism, ultimately leading to its logical conclusion in the Behaviorists' claim that overt actions could be the only possible object of a scientific psychology. The companion implication of Descartes' view—that behavior is triggered or stimulated by something in the environment of the organism—has persisted in psychology down to the present day in the form of the stimulus-response scheme.

Some writers have attempted to blend the stimulus-response concept with the feedback-control concept, in an attempt to solve the problems about external control of behavior. One was Boneau (1974), whose suggestion we noted above. Another, Staats (1981), stated that "... psychology is still in that state of development in which there is no accepted, unified, comprehensive theoretical framework... [and therefore, it should] marshall itself toward establishing an interest in such unification." He proceeded to argue that this could be done within the existing "stimulus-control" paradigm.

Powers (1973a, 1973b, 1978), on the contrary, argued the case that the stimulus-response paradigm and the control-theory paradigm are fundamentally incompatible. If one is right, the other must be wrong. To try to compromise or synthesize them would be like Galileo trying to satisfy the inquisition[2] by saying the earth *both* moved and didn't move.

An exhaustive review of all of the psychologists who consider that the field is in a state of "scientific crisis" would require a book in itself. Our aim here is simply to draw attention to the fact that there is a widespread sense of crisis among psychologists interested in fundamental theory. Before turning to the history of the current paradigm in our next section, we pause to note that one of the great pioneer psychologists, John Dewey (1896), never did accept the stimulus-response paradigm as an adequate foundation for psychology.

1.4 Models of Human Nature

1.4.1 *Reflexes and Associations*

Howard Rachlin (1970, 1976) presents a view of the history of modern Behaviorism (or, as he sees it, modern psychology) in his *Introduction to Modern Behaviorism.* He traces its roots to Cartesian Dualism, and he points out that in solving the problem of studying human nature empirically, without offending the then-dominant view that human nature was already fully explained by Christian doctrine, Descartes was forced to split the body off from the mind. He assigned the will to the province of the mind/soul—the spiritual side of nature—and he assigned involuntary, mechanical behavior to the body. He saw the body as simply a type of machine, the workings of which eventually would be explained fully by the same laws of physics which underlie the functioning of non-living machinery. Rachlin went on to offer this hypothesis:

> Descartes may have gotten the idea that many human behaviors could also be mechanical from watching the movements of the mechanical statues constructed by ingenious 17th century architects and hydraulic engineers. Many of these grotesque mechanical figures were activated... by internal forces (clockworks), but some had a unique feature—they were triggered... as the observer... stepped on a hidden treadle.... To Descartes this feature of the mechanism, their response to a signal from the environment, was critically important. He reasoned that if human behavior could be simulated so well by these mechanical figures, then perhaps some of the principles on which the mechanism operated also applied to the humans they were designed to imitate. (Rachlin, 1976, pp. 4-5)

Rachlin presented one of the diagrams from Descartes' *De Homine*—showing a person pulling his hand back from the "stimulus" of fire—to illustrate the meaning of the concept of "reflex." This drawing, as well as Descartes' even more famous depiction of a person reaching for an object as a result of the image (picture) of the object entering the eye and flowing along the nerves to the brain, illustrate the manner in which Descartes' views laid the groundwork for the notion that human behavior originates in stimulation from the environment.

Most subsequent writers seem to have picked up Descartes' notion of the reflex as the basic unit of behavior. Thus, William James (1890) in his monumental *Psychology* does not even mention the history of the concept of the reflex. He begins by describing it as the basic building block of behavior, apparently assuming it needs no historical explanation, because it is accepted by everyone as axiomatic.

The British philosophers of the 18th century contributed the second basic idea, "association," while accepting Descartes' concept of the reflex. The idea of associationism was that events which happen at the same time in the organism become linked. Thus the ground was ready for Pavlov, 100 years later, to explain his accidental discovery of the linkage of an environmental event (ringing of a bell) with the physiological "reflex" of salivation.

The ringing of the bell was the stimulus, or trigger, to which the built-in reflex of salivating became "conditioned" by association with the "natural stimulus" —food, according to Pavlov. Thus, stimulus-response, or conditioning, psychology was born. This combination of the idea of the reflex with the idea of association formed the paradigm upon which modern psychology was built.

Now we are asserting that there is no such thing as a "reflex." Clearly, we don't mean that Pavlov's dogs did *not* salivate when he rang a bell before feeding them. (A paradigm shift is a change in the way facts are perceived or explained, but of course the basic observations are still there.)

The conception we shall develop in this book is that living organisms are fundamentally different from the machines upon which Descartes formed his original ideas. The difference is more than degree of complexity; it is that *organisms* are environment-controlling, not environment-controlled. Where Pavlov talked about a feeding *reflex*, we might talk about a feeding control system. (Of course, "feeding reflex" is a short-cut expression. To be fair, Pavlov saw acts like feeding as chains of reflexes such as salivation, lowering the head, chewing, and so on.)

While it might seem only a simple substitution of words, this shift in viewpoint has revolutionary consequences for the whole study of psychology. In the above distinction, for example, if you are completely rigorous with your logic, the dog *must salivate* after you ring the bell, whereas the control-system model suggests the possibility that, if the dog already had a mouth full of saliva, there would be no new response to the ringing of the bell, because the specified condition was already met. In other words, behavior is controlled by conditions within the organism rather than by stimuli from the environment.

1.4.2 The Control-Theory Model

The control-theory model was derived from the confluence of several lines of thinking which go under the various names of "systems theory," "information theory," and "cybernetic theory." Many psychologists have been suspicious of control theory because of their mistaken impression that it is an attempt to analogize human behavior to self-regulating machines. However, Powers (1978) pointed out that the actual development was the other way around. In order for cybernetic engineers to create machines that would duplicate human behavior, it became necessary to examine human behavior in minute detail to see how it actually worked.

The engineers were aided at points in this process by analogies from the field of radio, particularly the concept of the feedback circuit.[3] Robot engineers and neurology researchers noted that this feedback model fits the control of body movements better than the older "reflex" explanations do. Then Powers (1973a) presented a model showing how *all* behavior can be understood in terms of a hierarchy of such feedback circuits—each level working to control perceptions specified by the level above. Since that time, various lines of investigation in psychology have begun to apply this new model to explain existing facts and to discover new facts.

1.5 What is a Fact?

A "fact" is defined formally in *Webster's Dictionary* (1980) as "a thing done... something that has actual existence, ... a piece of information presented as having objective reality." How one "knows" a fact is not included in the formal definition. However, the subject is important and difficult enough that special disciplines are devoted to working on the problem. Merton Krause (1973), in an article titled "What It Is to Learn a Fact," argued that both the criteria for deciding if one knows a fact and the means for coming to know it are different, depending on whether you are thinking in terms of examining your own experience in learning the fact, evaluating whether you have succeeded in teaching it to someone else, or judging whether someone, whom you are observing, knows it.[4]

Krause's article raises important questions about current research into many important topics in psychology: the nature of learning, what is happening in the nervous system during learning, and how the desired learning (rather than some surface appearance) can be judged reliably to exist. Most current research on learning is ambiguous because it fails to take account of the distinctions noted by Krause. The remedy we propose is to change our focus from "learning" to the question of how living organisms develop new control systems.

The control-theory model provides more readily objectified variables for study. Controlled conditions exist in the environment. You can tell when some condition is under control of a feedback system if disturbances of the controlled condition are immediately followed by changes back to the original state.

Thus, to take as an illustration the question Krause has asked about how to measure whether a student has learned what is really important, we begin by specifying what environmental condition must be kept in what state. If the student initially *cannot* keep that condition in the desired state and then later *can*, we call that control. We infer that a control system has come into being within his or her central nervous system for perceiving and regulating that condition. For example, a person who has learned to read cancontrolhisorherperceptionofa seriesofblackmarksonpaperintounits which he or she can identify as words even when they are not presented in the form of single units.

Once organized in the nervous system of a person, a control system (like the one needed for the above task) can then execute commands such as seeing a series of number symbols on paper as either (1) a set of random numbers (look at the numbers in blocks of three) 13141516171819202122232425262728293031, or (2) as a continuation of the sequence 123456789101112. Notice that how you "see" the upper line of numbers is not controlled by the environment; it is controlled by you, the organism. The "stimulus" is exactly the same in both cases.

In studying how the environment is brought under control, we find that control theory changes many aspects of psychological research. The topics of "learning," "perception," and "motivation" no longer are seen as separable processes, studied by different subdisciplines in psychology. They are viewed as *aspects* of environment-control, inseparably related in the feedback loop.

In the traditional way of analyzing experience, "sensations" are distinguished from percepts, as if they involved different kinds of mechanisms. For example, in *Webster's Dictionary* (1980), we find "sensation" defined as "a mental process (as seeing, hearing or smelling) due to immediate bodily stimulation... compare *perception*." "Perception" is defined as "... physical sensation interpreted in the light of experience...," and a "percept" is defined as "an impression of an object obtained by use of the senses: *a sense datum*."

In each of the above definitions, an arbitrary slice of experience is taken independently of the brain mechanisms that might underlie it. That happened long ago, probably because humans were interested in conceptualizing about experience long before we had any knowledge of the neural mechanisms of the body. Later, as neuropsychology grew, its discoveries were confined to the pre-existing "common-sense" categories, with the resulting confusion about how things actually work.

As we have gained some understanding of neurology, we have begun to alter how we conceptualize our information. That is what we are doing in introducing new theory. For example, the most elementary type of controlled variable can be called *Intensity*. It is defined in terms of the flow of impulses along a nerve, originating from a specified type of sensory receptor (technically called a transducer). Then, instead of studying "sensation" as an isolated process, we begin with the physical and physiological properties of sensory transducers and how they initiate nerve impulses, playing their part in the complete control circuit.

At the second level of control, the traditional term *Sensation* is defined as the vector of a set of Intensity signals. Next, there must exist a means of isolating objects out of a welter of sensations. When several sensations are controlled together in a unit, they provide the elementary experience of *Configurations*. Thus the sensing of light and dark contrasts creates the perception of a line.

This scheme admirably fits Hebb's (1949) report that basic elements of what were once thought primitive *Gestalts* in fact have to be learned by the developing organism. Such percepts as *corners*, *edges*, and *spaces* which once were thought to be elementary qualities of passive perception are actually constructed by actions such as movements of the eyeball.

"Facts," traditionally defined as "piece[s] of information... having objective reality," are still further removed from the underlying mechanisms. What is "objective reality"? If we take that to mean only things which have physical existence, then you cannot say it is a fact that two and two equals four. That is a logical concept. To remedy this difficulty, psychologists have defined the concept of "consensual validation" as a type of objective reality by which we can make such statements.

"Consensual validation" is agreement by a relevant group of people that they all have the same thing in mind when using the same set of words. This procedure works fairly well with objects, relationships, and processes which exist in our physical environment. There usually is not much trouble in stating, "My dog is black," if your listener can see your dog at the time. (Although, suppose the listener says, "Actually, he looks more like very, very dark brown to me." You then set up a procedure for drawing an unambiguous distinction, and agree to abide by the results.)

But if you say to me, "My dog is conditioned to bark when I ring this bell," and I say, "No, I'll grant that he barks when you ring the bell, but it's not because he is conditioned, it's because you forced him to develop a control system for hearing himself bark after he hears the bell," then we have a problem. Either we must use the term "fact" only for events which have pre-existing procedures to help achieve consensual validation, or else we must grant that "facts" (at least abstract facts) exist only within explanatory models. In that case, we can agree on the facts only if we are employing the same model.

In keeping with the argument above, we shall strive to reduce definitions and descriptions in the research we describe to the concrete events or measurements on which they were originally based. That will keep "facts" in such descriptions separate from the theoretical interpretations with which they were observed. Such a procedure will involve reducing many descriptions to everyday language, leaving out the technical jargon.

For example, where traditional theory talks about "motive," we look for a description of the conditions necessary for the behavior in question to occur. Then we look for the state of those conditions which the person intended to maintain. We expect to see the person (or any other organism) taking action to return those conditions to their intended state whenever they depart from it. This is control, and we never need the word "motive" at all. Or you could say that "motive" boils down to just one thing: A living organism always has the "motive" of maintaining its environment identical to the way it "intends" to perceive it (within the limits of its abilities). An organism may have *reference signals* of different strengths in its various control systems, of course, and there thus will be priorities observable in its actions. These differences in priority have sometimes been studied under the topic of "motive" in traditional psychological research.

1.6 How Facts Are Established within Models

In 1961, J. McV. Hunt, a leading psychologist in the field of personality, published a book titled *Intelligence and Experience*, intending to overturn a major belief of many psychologists of his day—that intelligence is a genetically fixed quality. As he states in the Preface to his book:

> For over half a century, the leading theory of man's nature has been dominated by the assumptions of fixed intelligence and predetermined development. These beliefs have played a large role in psychological theorizing and... the development of human abilities... [has] been regarded as the unfolding of capacities almost completely predetermined by inheritance. Recently, however, a transformation has been taking place in this traditional conception of intelligence and its relationship to experience. Evidence from various sources has been forcing a recognition of... the crucial role of life experience in the development of these central processes....
>
> This book... examines the historical roots of the assumptions of fixed intelligence and of predetermined development and the evidence that was interpreted to support them.... The observations of Piaget and his collaborators on the development of intelligence and logical thinking... help to show how the human brain is "programmed" in the course of the experiences of living... this evidence leads to a serious questioning of the immutability of the IQ.

Hunt went on to propose a new model of human development which differed from the previously dominant view—that intellectual capacity is determined by genetics and develops after birth through predetermined maturational processes. His new model took for evidence, and in turn helped to make sense of, a number of findings which originally were considered so bizarre by established experts that the facts discovered by younger investigators simply had been rejected and not recognized as facts.

Hunt cited as a prime example the now-famous report of Skeels and Dye (1939), which, according to Hunt, was greeted with derision by other psychologists when it was published. Skeels and Dye made a surprising clinical discovery. Their report involved two children from an orphanage who had been removed to a home for the feebleminded because of their low IQs and generally lagging maturation, and placed in a ward for feebleminded girls. Six months later, they had made surprising gains in IQ; a year later they had reached approximately normal development. The explanation appeared to be the interest and affection shown to the children by the older feebleminded residents of the ward. The result was confirmed by a further study in which another group of orphanage children were distributed in such wards.

Skeels and Dye's results were greeted with derision because the "maturation model" dominant in developmental psychology in their day did not accept the belief that such a nebulous quality as "mothering" could have tangible effects on development. Today this view is no longer fantastic, as a result of the work of R. A. Spitz (1945, 1946), John Bowlby (1969, 1973), Harry Harlow (1958, 1979), Margaret Mahler (1975), and others.

Even though Hunt saw the necessity of a new model for understanding development, he tried to keep it within the dominant Cartesian paradigm in psychology. He struggled to make it fit, especially with respect to Piaget's work. He concluded that the more physiological levels of behavior might be explained in terms of reflexes, but that higher levels must be accounted for in some other terms.

Paradigm shifts are much too fundamental to allow the new views simply to build on the old ones, Kuhn (1962, 1970) argued. Theorists will not readily give up the basis upon which their theories are formulated; instead, either they evaluate the facts to fit with existing theories—as the developmental experts of Skeels and Dye's era did, or they keep revising theories as long as possible to encompass new facts, as Hunt was trying to do. But the "fit" gradually becomes worse and worse. It will help you understand this if we get outside the scope of psychology and view the process of theory building and the use of evidence as the philosopher of science sees it.

Consider the following discussion from a text on logic and scientific method (Cohen & Nagel, 1934), in a chapter on "Hypotheses and Scientific Method." Among other things, it is meant to illustrate how the average person tends to accept the "facts of nature" at face value without ever wondering about underlying causes.

> In the second book of his fascinating *History*, Herodotus recounts the sights that met him on his travels to Egypt. The river Nile aroused his attention:
>
>> Now the Nile, when it overflows, floods not only the Delta, but also the tracts of country on both sides of the stream....
>>
>> Concerning the nature of the river, I was not able to gain any information [about] why the Nile, at the commencement of the summer solstice, begins to rise, and continues to increase for a hundred days—and why, as soon as that number is past, it forthwith retires and contracts its stream, continuing low during the whole of the winter until the summer solstice comes around again. On none of these points could I obtain any explanation from the inhabitants, though I made every inquiry.... They could [not] tell me what special virtue the Nile has which makes it so opposite in its nature to all other streams....
>>
>> Some of the Greeks, however, wishing to get a reputation for cleverness have offered explanations of the phenomena of the river, for which they have accounted in three different ways. Two of these I do not think it worth while to speak of further....
>>
>> The third explanation... more plausible than either of the others, is positively the furthest from the truth.... It is that the inundation of the Nile is caused by the melting of snows. Now as the Nile flows out of Libya (Central Africa) through Ethiopia into Egypt, how is it possible... running as it does, from the hottest regions of the world into cooler countries? Many are the proofs whereby anyone capable of reasoning on the subject may be convinced that it is most unlikely this should be the case....
>
> Has the reader ever been guilty of believing or saying that the way to find out what the truth is, is to "study the facts" or "let the facts speak for themselves"? Then let him examine this quotation for the light it may throw on [how] contributions to knowledge are made. We have suggested... that unless habitual beliefs are shaken into doubt by alterations in our familiar environment or curiosity, we either do no thinking at all, or our thinking, such as it is, has a routine character....
>
> This excerpt from Herodotus illustrates... the great difference between the habit of simple acceptance of apparently stray, disconnected information, and the attitude that searches for some order in facts.... The inundation of the Nile was to many a brute fact, unconnected with other familiar but isolated facts. For Herodotus, however, the behavior of the Nile... presented a problem [of the] connection between the periodic inundation of the Nile and other facts.
>
> It is an utterly superficial view, therefore, that the truth is to be found by "studying the facts." It is superficial because no inquiry can even get under way until and unless some difficulty is felt in a practical or theoretical situation. [That is what] guides our search for... tentative explanations [which] are suggested to us by something in the subject matter and by our previous knowledge. When they are formulated as propositions, they are called hypotheses.
>
> The function of a hypothesis is to direct our search for the order among facts. The suggestions formulated in the hypothesis may be solutions to the problem. Whether they are is the task of the inquiry. (pp. 197-202)

Thinking back on Skeels and Dye's report in the light of the above, you can see how, if you already "knew" that intelligence could *not* be affected by nurturing practices, there is no mystery in their finding; it is simply an error, probably a result of faulty observation or poor measurement. And that is what the critics mentioned by Hunt said. In order for a finding to be accepted as fact, and to require an explanation, it is first necessary to have a framework—a model—in which it could be a fact. (Even then, the model is pretty weak if it only allows one to state, as in the years just before Hunt, that "the quality of nurturing does seem to affect development, but no one knows how that works."

In the case where a model offers no suggestion as to how the observed phenomena might work, the problem of the scientist is not that of fitting the facts into his or her model. It is that of comparing different models to find the one which might be capable of handling the facts.

1.7 Models, Evidence and Proof in Psychology

The term "theory" is not well defined in the science of psychology. There are at least three different processes of generalizing from observations, all called theorizing: (1) extrapolation; (2) abstraction; (3) model building. Extrapolation is based on the assumption that observations which occur regularly will continue to occur regularly. For example, if the students in many psychology classes prove able to remember about seven digits read off to them at a uniform rate, it is natural to extrapolate that future groups of people will perform similarly. When the observation has been repeated often enough to satisfy one's feelings about reality, we begin to call it a fact.

> Extrapolation fails because conditions change [or] observations may be made at a time when the true state of affairs cannot be seen, and most often, in psychology, because the phenomena themselves are subject to unpredictable variations.... There are two ways to deal with random variations: average them out or trace them to their causes. The causes of most behavioral variations are not known, hence psychologists turn to statistics to render their extrapolations less variable. One no longer says, "rats will eat food," but, "94 out of 100 will eat food." (Powers, 1973a, p. 12)

Another example, going a step further: a businessman expects aptitude tests to give a better guess about the number of new employees who will stay on the job than the foreman's judgment could give, on the average. But the aptitude tests can improve only the probability of being right for a *group* of people. They cannot predict the behavior of any particular person.[5] Since statistics may reveal stable relationships, which cannot be seen without averaging, we then search for abstract (statistical) generalizations which can be used in place of individual observations. For example, "intermittent reinforcement results in behavior which is harder to extinquish than that built up with continuous reinforcement." The terms "intermittent" and "continuous" do not refer to any particular schedules of reinforcement, they refer to whole classes, and are terms which name the classes, rather than any particular schedule. (The problem with this, however, is that individual behavior which does not conform to the statistical generalization often tends to be treated as if it did not exist.)

Psychology previously has been built almost exclusively with theories of types (1) and (2) rather than with model building. Although many "theories" in psychology have been called "models" by their authors, and we have accepted the term "model" in this loose sense when quoting the authors above, it will be worth the effort to define and use the term in the more precise sense of the physical sciences hereafter.

An illustration of a true model in the sense of the physical sciences is the astronomical theory of Copernicus. The conception of the universe as a system of spheres floating in space, held together by some (as of then) unknown force, could be simulated, in principle. The essential relationships could be perceived by actually building a material model (a lamp as "sun" shining on a set of globes suspended on wires, including the earth with a smaller globe revolving around it). Such a model would permit the mysterious patterns of movements of the planets noted by astronomers to be seen directly.

What is presented below is a model of the functioning of the human organism —in the sense of a hierarchical arrangement of control systems, the actions of which can be predicted by simulations and tested as to how well the simulations fit. If the predicted behavior in the simulation parallels the actual behavior of people in the circumstances of interest, we regard that as evidence supporting the model.

Consequently, "prediction" takes on a different meaning from what it has previously had in psychology. Rather than meaning successful extrapolations about the behavior of individuals,[6] "prediction" now means drawing implications from theory about observations which never have been made previously, and testing the theory by attempting to confirm or disconfirm them in the real world.

1.8 A New Direction for Psychology

If we are proposing a new direction for the science of psychology rather than the current meaning of "prediction and control," what is it? In brief, we shall say it is *understanding*. We are interested in how the human organism "works." (And also how animals "work," believing, as we do, that all organisms are basically structured along the same general principles.) Understanding is more basic than "prediction and control." Science has gained considerable understanding of the nature of the universe, but that has brought only limited prediction, and no control.

We ordinarily govern our own actions, taking our current knowledge into account, and hence we change our behavior toward other humans as we gain greater understanding about how humans "work." To say that we behave toward ourselves and others in accord with our current beliefs about how people work is not a trivial point. One of us (RJR) has learned through many years of teaching college students that there is an all too common tendency to see psychology as a means for learning to influence other people, without necessarily increasing one's knowledge about oneself.

Psychotherapists have long been telling their clients that that doesn't work. If you aren't satisfied with your relationship with another person, they say the way to improve it is to change yourself. But that advice often is not heeded. It runs counter to the "common-sense" (but false) view of humans (as entities responding to outside stimuli) which has dominated psychological thinking since Descartes introduced it almost 400 years ago.

We believe this tendency to view psychology as knowledge about how to control the behavior of *other* people results from an ultimate implication of the stimulus-response approach—in which the psychologist, as researcher and professional, is seen as an uninvolved experimenter. Thus, students are unconsciously led to think they are being most scientific when viewing other people as objects. From there, it is a short step to think that controlling other people for one's own purposes is a legitimate goal of scientific psychology.

There seems some superficial evidence that this goal can be achieved. For example, the current success of advertising and marketing research. You might have heard of "subliminal suggestion"—by which people supposedly are "made to buy" things they don't want, are influenced not to shoplift, or the like. So powerful is this technique thought to be by some that laws are being passed to prohibit or regulate its use. The application of psychology in advertising and public relations is taken by some people as evidence that behavior can be externally controlled.

What psychologists know, however, is that such techniques "work" mainly by showing people how to meet needs which they already have. Where the techniques seem to overpower the "subject's" short-run self-interest, the keen investigator finds that they do so by appealing to one of his or her other purposes. For example, when people are influenced to buy cars, furniture, and homes with fashionable addresses—to enhance their social status—though they might not originally have wanted that particular product or property, they did want the status.

As you come to see behavior from within the control-theory model, you might suspect that the hope of "understanding" people for the purpose of controlling them is illusory. It is difficult, if not impossible, to control others for any length of time, as tyrants and psychopaths keep demonstrating. People may accept the influence of others when their purposes are in harmony, but the only sure way to make people do what they don't want to do is by controlling their food or air supply or by the use of overwhelming force. Consider how this changed belief might affect our approach to the science of psychology.

The question of whether you ever can learn enough about human beings to know what any given one will do next, and hence be able to forestall, or "control" it (the dream of every dictator) becomes a question not of the *aim* of science, but rather a question of *fact*—for science to investigate, as to whether or not it is true.[7]

Notes

1. If a single "stimulus" supposedly is affecting everyone, regardless of their individual intentions, then its effects could show up only as a slight average tendency. Such research fails to make clear that its "facts" actually come from averages in groups of individuals in which some did the opposite, and some acted irrelevantly to the issue—only a portion acted in the expected direction enough to determine the average results.

2. The inquisition was inquiry (often by means of torture) by agents of the Roman Catholic Church into whether a person accepted established beliefs.

3. A feedback circuit is one in which some condition of a phenomenon is sensed or detected, and variations in its degree or magnitude are controlled by the system's mechanism, working to keep the sensed signal matched to a specific value or reference signal. The intensity or magnitude of the sensed signal is compared with the reference signal, and any mismatch is corrected as the output varies, however necessary, to drive the controlled condition back toward its reference state.

4. Krause questioned whether the typical classroom situation, where "facts" are presented to groups of students, ever can accomplish more than training students "to make certain stylized gestures in response to appropriate commands."

5. "It is unfortunate but true that measures and predictions obtainable only through averaging the performance of many persons are applied to individuals, so that a person's life may be affected by his performance on a test that is valid only for predicting behavior en masse...." (Powers, 1973a, p. 12)

6. For example: if only you had good enough personality tests, and a sufficiently smart formula for putting them together, the assumption is that you could tell what any subject would do in response to any stimulus.

7. You should understand that the control-theory model is not given in terms of the known facts of the nervous system, because it is a model of any control system capable of doing what humans do, independent of whether it consists of biological or electronic components. Once the model is presented, it can be tested to see how well human functioning can be understood by using it.

Chapter 2

Scientific Psychology: Behavior and Control

2.1 How Behaviorism Became Dominant

Psychology has been defined in different ways. Early definitions tended to view psychology as the study of mind. It came to be defined as the study of *behavior* with the ascendency of Behaviorism as the dominant approach. This definition was thought superior because it satisfied the requirements for science laid down early in the present century by the Logical Positivist school of philosophy, holding that the only genuine knowledge is that obtained by *objective* techniques or procedures. "Objective" procedures mean that I can duplicate what you did to achieve the same experience. Another way of saying it would be that the only facts on which we can definitely agree are those which can be obtained by the senses of touching, seeing, hearing, tasting or smelling.

John B. Watson, the father of American Behaviorism, adopted this view of science in attempting to develop a more scientific psychology. He selected behavior—external, observable activity—as the only fit subject for scientific study by psychologists.

It might have been coincidental that Pavlov's (1937) studies of "conditioning" were the most notable new facts about behavior at the time Watson was looking for a way to make psychology more "scientific." (It probably was not wholly coincidental, because the same Zeitgeist was behind both developments.) Although Watson's desire to objectify psychology might have focused upon some other phenomenon, since Pavlov's work happened to dominate the attention of those interested in scientific psychology just then, Watson took "conditioning" as the basic concept in Behaviorism. "Conditioning" was based upon the Cartesian paradigm: *Stimuli* from the environment cause, or trigger, reflexive *responses* within the organism.

The already existing work of the Structuralist (Wundtian) school of psychology was equally qualified to meet Watson's requirement of "objectivity," in that the Structuralists also studied externally measurable capacities, such as how small a difference a human can detect between the weights of two objects (psychophysics), and how many times one must rehearse a poem (or set of nonsense syllables) in order to recite it from memory (early learning theory).

But Pavlov's work went beyond the work of the Structuralist school in one important sense. It investigated the formation of associations between seemingly unrelated actions and/or events. That went beyond simply reporting new facts, as the Structuralist studies did. (The American, Twitmeyer, previously had discovered the same thing as Pavlov, but his report did not cause any great stir, probably because the world of psychology was not yet ready for it.)

The English psychological philosophers, including Hume, Locke, and Berkeley, had speculated that learning consists of the formation of an association between two ideas. Subsequent psychological theorizing continued to accept this notion as a basic premise. Watson was not interested in ideas, because they could not be subjected to objective measurement, but he did accept the associationist premise about learning. Pavlov's results satisfied Watson's criterion for objectivity. They dealt with associations between externally observable events—the ringing of a bell and the dog's beginning to salivate. Thus, Pavlov's work remained within the tradition of associationist psychology, but added the feature of dealing with "behavior." It thereby appeared to dispense with the "useless" concept of "mind," as Watson wanted.

To get a more detailed picture of how Watson developed this line of thought, consider his famous "little Albert" experiment (Watson, 1920). Watson had begun his studies with an interest in infant behavior, looking for innate (unlearned) behavior. He was interested in developing a catalogue of instinctual "reflexes." He observed infant behavior starting right after birth, looking for the very first movement- and emotional-reflexes. Watson saw himself as carrying on from Pavlov's work in looking for counterparts of basic physiological reflexes, such as the salivary reflex. Sneezing and the startle reflex of the infant are such basic reflexes, in his view. He concluded that there are only three fundamental emotions, fear, anger, and love, and that they, too, are basic reflexes. He decided that fear is elicited by only three types of unlearned environmental stimuli —loud noise, pain, or sudden loss of support. All other behavior was to be understood as the result of the conditioning of these basic reflexes to previously neutral stimuli.

To test this theory, Watson took an 11-month-old child, Albert, and first demonstrated that Albert showed no fear of a rabbit or a laboratory white rat. Then Albert was presented the animal again; this time, when he took it, a steel bar was struck loudly behind his head. This procedure was repeated until Albert showed a distinct "fear reaction" of throwing up his arms, crying, and turning away whenever the rat was brought into his view. Interestingly, many introductory psychology texts have reported the experiment in greatly abbreviated form, seeming to suggest that the "fear reaction" occurred immediately and was invariable. Recently, that view has been corrected (see Samelson, 1980), revealing that the "conditioning" was anything but the perfect example which it had been thought to be for so long. We now can see this as an instance of the way in which the currently dominant paradigm in a science will influence how an author views his facts. Watson's own behavior was controlled by a "reference signal"—his personal commitment to the belief that learning must be the result of conditioning. Therefore, he perceived the facts to match his foregone conclusion in reporting his findings.

2.2 "Behaviorism" as a Paradigm

What exactly had Pavlov discovered? In his autobiography (quoted in Sahakian, 1970), Pavlov says:

> I shall mention two simple experiments that can be successfully performed by all. We introduce into the mouth of a dog a moderated solution of some acid. The acid produces a usual defensive reaction in the animal: by vigorous movements of the mouth, it ejects the solution,

> and at the same time an abundant quantity of saliva begins to flow first into the mouth and then overflows, diluting the acid and cleansing the oral cavity. Now let us turn to the second experiment. Just prior to introducing the same solution into the dog's mouth, we repeatedly act on the animal by a certain external agent, say, a definite sound. What happens then? It suffices simply to repeat the sound, and the same reaction is fully reproduced—the same reaction and the same saliva. (Pavlov, 1934)

Note how carefully Pavlov describes the animal's movements and the effect of acid upon the secretion of saliva. Contrast that with what he is not careful about. He does not bother to mention that the dog must be strapped rigidly into a harness for the experiment to be done at all. Nor does he define what he means by the term "repeatedly." Nor are the animal's struggles to escape from the experiment regarded as "behavior," and the number of times the experiment must be repeated before the conditioning is learned also is not taken into account.

Pavlov discovered a new "fact," but he did not break with tradition. He remained within the paradigm established by Descartes. He saw the phenomena he described as the response of pre-existing reflexes to stimuli from the environment. What was new was his belief that "neutral" phenomena of the environment can become stimuli by association—that is, by happening at the same time as the"natural" stimuli.

An American Behaviorist, H.S. Liddell, saw more importance in those aspects of the experimental situation that Pavlov ignored. Liddell (1944) had begun studying "experimental neurosis" following an accidental discovery of Pavlov. The latter had trained a dog to salivate after the presentation of a luminous circle of light on a screen. Then the animal was trained to discriminate between the circle—as a signal for feeding—and an ellipse of the same brightness and surface area—which was *not* a signal for feeding. When the animal had learned to make this discrimination, the aperture of the projector gradually was altered to make the ellipse more circular. When the ellipse axes reached a ratio of about 9 to 8, the animal could no longer tell the difference between the two "stimuli." It then began to resist being put into the harness, to squeal, to bite at the apparatus, and to fight against being brought into the testing room. This phenomenon came to be called "experimental neurosis." Liddell reported that he became interested in "experimental neuroses" following a laboratory accident similar to Pavlov's experiment. In studying the effects of thyroidectomy on sheep and goats, he had been surprised to find that this severe physiological damage had not affected their ability to learn to find their way through mazes, except for long pauses (presumably due to lowered energy). So, to continue the study of learning with these animals, he tried to adapt Pavlov's method of the conditioned reflex.

Since the salivary "reflex" in sheep and goats is more complicated than it is in the dog, Liddell switched to a different reflex. He trained his animals to raise a leg upon hearing a buzzer, so as to avoid a mild electric shock to the foreleg. As a consequence of these investigations, he came to a startling conclusion:

> During the course of our study of conditioned reflexes from 1927 to the present (that is, 1941), I came to believe that Pavlov's method of the conditioned reflex could be accurately characterized as a method for producing the experimental neurosis... the most significant feature of the conditioned reflex method is to be found in its monotonous and unsatisfying repetitiveness. The animal, having become accustomed to standing in the Pavlov frame, does so willingly and quietly and, during the experimental period is subjected to repeated and trivial stimuli... by signals which indicate that food or no food, shock or no shock, is about to follow. The extremely mild electric shock... can have but little import for the animal's well-being. The reinforcing agents... cannot be... important goals polarizing the animal's behavior....
>
> In the course of months or years of training in the conditioned reflex laboratory a progressive change in the animal's behavior moves toward the pathological "experimental neurosis."

> The situation, as we now view it, appears as follows. Domestication itself imposes on the animal restrictions and pressures, a hierarchy of them.... From this account, it can be seen that the perplexing problems facing the animal in the conditioned reflex laboratory represent restraints and pressures situated at the apex of a pyramid. Progressive restriction of liberty and correlative increase in pressures (similar to those exerted by society on the human individual) extend from the wild state, through domestication, to the too refined training of the laboratory. (Liddell, 1944)

Here we have a shift in view on the part of an early Behaviorist as to what to consider the important fact. He concluded that, in attempting to simplify the study of behavior, the inventors of the S-R paradigm had ended up calling something extremely complex, "simple," and, in addition, had tried to base the study of behavior upon the reaction of animals to highly unnatural conditions.[1]

Why didn't Liddell's concerns have more impact upon the development of Behaviorism? The answer seems to be complex. For one thing, Liddell's criticism was just that—it pointed out a problem without suggesting a cure. Another factor was that the implications of Watson's basic idea had not yet been played out fully.

There was one impressive advance in Watson's notion that psychology be restricted to objective investigations. Psychologists could attempt to pursue all areas of the field, not just psychophysics, with replicable studies. True, there was a price for this. Much that might be subjectively important simply would have to be ignored or covered over with facile language, but many topics which previously had been dealt with only by speculation could be given objective (if oversimplified) "operational definitions." To appreciate both what Behaviorism accomplished and where it fell short, we turn to the work of B.F. Skinner.

2.3 What Behaviorism Accomplished

In order to appreciate Skinner's (1938) contribution, let us back up and take another look at the basic stimulus-response (S-R) paradigm. If it never occurs to you to question Descartes' original assumption that behavior is caused by stimuli from the environment,[2] it is undeniably elegant to formulate so basic a law as S→R. It has the same dramatic appeal as, for example, $E = mc^2$.

Starting from this formulation, then, the task becomes not that of deciding whether S→R is fundamentally right—that is assumed to begin with—but of defining S and R so as to be able to "turn the crank" and work the formula. This Skinner did brilliantly. Professing to be uninterested in theoretical models or philosophical quibbles, he concentrated upon training animals, and training laboratory assistants to train animals, so as to obtain finer and finer differentiations in their actions. From a scientific point of view, the most interesting part of modern Behaviorism is the lore of training—that by-now-great body of skill in arranging restraints and conditions to allow subjects fewer and fewer options for spontaneous behavior (leaving only what is desired by the experimenters). This *is* lore, however. It does not appear in textbooks on learning, except here and there for illustrative purposes. Lore does not contribute to theory-building, since it is simply the body of techniques which people working in a given field use to adapt their general approach to specific situations. What Liddell (1944) called the most interesting aspect of behavior, the relationship between subject and experimenter, is buried as miscellany in the reports of Skinner and other Behaviorists, when reported at all.

Nevertheless, this attitude had some very positive consequences. Operating with the view that environmental conditions, not limitations in hereditary endowment, are the determining factors in the molding of behavior, the Skinnerians developed the lore of training to great heights, unhindered by preconceptions about what might be possible. (This produced the applied discipline called "behavior modification.") They carried out Watson's boast that, given control over the conditions, one could train any child (or animal) in any skill, with some interesting results. But they could not fully realize the boast, because this view has limitations, as you will see below.

2.4 Where Behaviorism Falls Down

Currently, psychology textbooks based upon the traditional Behaviorist paradigm generally include a section in their chapter on learning in which they acknowledge behavioral phenomena which are not readily explainable in terms of either operant or respondent conditioning, the two general classes of behavior distinguished in Skinnerian theory by the purportedly different ways in which they are learned. These categories of conditioning-defying behaviors go by such names as "instinctive drift," "autoshaping," "biological constraints," "taste aversion," "insight," and "cognitive maps." (Lefrancois, 1982)

Instinctive drift refers to the phenomenon in which animals trained by operant conditioning methods fail to continue to display "conditioned" behavior on cue. Instead, their performance shows a drift toward typical, instinctive behaviors of their species (Breland and Breland, 1961).

Autoshaping is the term given to behavior which an animal appears to learn without being reinforced. Since conditioning theory postulates that learning results only when there is reinforcement, this kind of behavior may be regarded as refuting conditioning theory. It has been rationalized by some Behaviorists by saying that the reinforcement must be internal to the organism. However, that type of explanation is a violation of the Behaviorist paradigm, which states that only externally observable actions are fit for the study of psychology.

Biological constraints is the term used to cover the whole range of species-specific or instinctive "knowledge" which different species seem to have about what is and is not good for them.

Insight is the perception of relationships between phenomena or facts not previously seen as related.

Cognitive maps is a term introduced by Tolman (1932) to account for several types of behavior observed in rats placed in different learning experiments. In one type of experiment, rats showed that they had learned their way around a maze in which they simply had been allowed to wander without any reinforcement. In another of Tolman's experiments, rats showed that they seemed able to imagine the whole layout of a maze, although they had been trained only to find their way through part of it. Tolman, as an early opponent of the conditioning model in learning theory, argued for the concept of *purpose* in the study of behavior. However, his work predated the control-theory paradigm. He was able to raise difficult questions for Behaviorist theory, but he was trying to remain within the traditional paradigm.

Let us recall the basic tenet of Western psychological thought from Descartes down through modern Behaviorism. It is not associationism, or conditioning (learning by associating act and reinforcement); it is that the environment controls the organism. It is also important to remember that there are different ways of saying this. If you forget that, it becomes all too possible to think that the alternative formulations actually provide new information, when, in fact, they only are stating the same thing in different ways. Some other ways of saying that the environment controls the organism are "stimulus causes response" and "perception controls behavior."

A great deal of thinking has been invested in the S-R paradigm, and so it will be extremely difficult to replace it with its opposite, "behavior controls perception." To those already "conditioned" by the Cartesian paradigm, this statement appears counterintuitive. You can start with just about any kind of description of any kind of behavior. For example, you wake up in the morning, open your eyes, and a ray of sunshine coming in through the window and falling on them "causes" you to close them again. It seems to make good sense to say that the stimulus caused the response, or the perception caused the behavior.

It seems more complicated to explain that the action of closing the eyes occurred because a control system, set to maintain a given range of light intensity, had corrected the "erroneous" perception (of too much light) with appropriate action (snapping the eyelids shut). Why would you want to retrain yourself to view reality with a new paradigm which seems only to make matters more complicated? For some psychologists, the exceptions to Behaviorist explanations noted above are enough to make them want an alternative way of explaining things (see, for example, Carver and Scheier, 1981, 1982). However, the contrary view is more common, as exemplified by the following statement from a section titled "Current Directions in Behaviorism" in one introductory psychology textbook (Lefrancois, 1982):

> The explanatory powers of traditional behavioral theory do not easily encompass these diverse findings. Instinctual drift, autoshaping, delayed taste aversion... all present serious problems for traditional behavioristic theories.... Do the findings invalidate the theories? And should they lead us to discard the theories completely and to search for new explanations?.... The answer is no....

The present book is one in which the answer is *yes*. It is yes because we do not agree that satisfactory models can be constructed using the Cartesian paradigm. As Powers (1973a) has argued, there are many explanations current in psychology which are called "models," but which do not conform to definitions of "models" widely accepted in the natural sciences and mathematics. Some of the "models" in psychology are beginning to show features similar to the "epicycles upon epicycles" which characterized the Ptolemaic theory in astronomy prior to its demise.

It is also not the case that control-theory explanations are more complicated. They seem more complicated when applied to something you already "understand," as was the case in the example of closing one's eyes in bright sunlight. When you already "understand" something, it is superfluous to examine it in new terms. However, as Powers (1979a, b, c, d) has indicated, if you want to build a robot which could protect its eyes from too bright sunlight, you could not do it along the lines of the Behaviorist explanation, but you *could* do it following the control-theory explanation.

Finally, it is also not the case that the control-theory model has added nothing in the way of new facts about nature. One discovery which emerged as a theoretical deduction from the early formulation of the control-theory model shows the "nesting" of reaction times within a series of simple acts, each of which can be viewed as behavior within itself or as a component of a larger chunk of behavior.

2.5 Self-Demonstration of a Human Control Hierarchy

To demonstrate several "nested" control systems in the body, begin at FIRST ORDER, which is exemplified in the spinal reflex loop. A subject (S) extends his or her arm in front of himself or herself, with instructions to hold it steady, and the experimenter (E) places his or her hand lightly on top of S's. E should make sure that S is not holding his or her arm limp. E then gives a sudden sharp downward push, and S's arm appears to rebound as if on a spring. An electromyograph verifies that this is an active, innervated correction, not simply muscle elasticity. The initial position of S's arm makes no difference, and the initial muscle tensions involved also make no difference. S can be asked to hold his or her arm in a different position, and the control action will be the same, showing that the reference signal for the system can be altered and the system will continue to correct its action to the new reference setting.

SECOND-ORDER SYSTEMS derive their feedback signals from sets of first-order feedback signals. We call this level of control, or second-order feedback (f-2), "elementary sensations," since it represents the initial grouping of first-order (f-1) signals into elements with characteristic sensory patterns. In the kinesthetic modality, there would be signals representing muscle stretch, joint angle, tendon tension, and internal tissue pressure—which add up to the elementary sensations of effort, as when you clench your fist. To demonstrate this order, E now instructs S to extend his or her hand as before and E again places his or her hand on top. Now E tells S to swing his or her arm downward as rapidly as possible, as soon as he or she feels E's downward push. E's hand must be in contact with S's to make the push as sharp and unexpected as possible. Immediately upon the push, S's first-order systems return his or her arm to its initial position, because they act within the latent period of the second-order feedback signal. The initial correction is nearly completed before the second order resets the reference signal.

THIRD-ORDER CONTROL. Third-order variables are named "static configurations." They combine classes of sensation feedback. E instructs S as in the second-order demonstration, but now requesting that the movement be made sideways, again making the initial press in the direction of motion. Now, however, E extends his or her other hand, holding out his or her index finger, instructing S to swing his or her arm over to touch the index finger to E's upon the signal. At the instant of the push, E shifts his or her target finger 4 or 5 inches from its initial position. The first two orders of action remain visible, and at the end of S's rapid swing, a third phase can be seen. S's finger comes nearly to a stop where E's finger *was*, and then shows a much slower corrective movement which is noticeably different from the first two actions. The second-order systems achieve their goal states much more quickly than third-order systems—so quickly that under appropriate circumstances they actually have to wait for the next reference signal from the controlling third-order system.

FOURTH-ORDER CONTROL is the control of transitions between different static configurations. E instructs S to extend an index finger and track E's extended index finger. E then moves his or her own finger in a circle 8 to 12 inches in diameter, gradually speeding up. You can notice S first tracing a jagged path while attempting to match E's position, until he or she experiences the regularity of E's movement—at which point S's action smooths into the appropriate circular pattern; he or she has set the reference level of a fourth-order system. The variables of this level are called transition control variables.

Studying behavior within the control-theory paradigm is a different process from that of traditional psychology. Instead of describing an activity of interest to the experimenter (often arbitrarily chosen) and then creating theoretical explanations independently of explanations in other areas of psychology, we first need to present the control-theory model as a whole. Then we shall be able to examine each level of behavior in relation to the others and use comparable rather than incomparable terminology in studying them. The above demonstration comprises a prelude to this process.

2.6 How Does This Affect Psychology's Future Direction?

Instead of saying that we intend to make the study of behavior more scientific, or the study of the mind more scientific, let us agree that we want to make *psychology* more scientific. What does this mean? Consider the case of physics. When the (apocryphal) apple bounced off the head of Sir Isaac Newton, he is said to have realized that the falling of leaves (or apples), the flowing of water, the path of the moon in the night sky, and the discomfort which people experience when they stand on their heads all display the same fundamental aspect of nature: gravity. You can't see, hear, taste, smell, or feel gravity. (That's right, you can't feel it. What you feel is the greater effort it takes to climb a tree or stairs than to come down. You feel the "pull" downward if you lean too far forward or backward, or slip on a banana peel. But you feel that as "pull" because, since Newton's time, we *understand* our experience of muscular effort with the help of the concept of gravity.)

"Gravity" is a construct which, once constructed, makes it possible to describe the falling of objects and the orbits of moons and planets with the same formula. Newton's task required turning his interest away from common-sense reality to create a theoretical model which cannot be glimpsed from common-sense reality. Control-theory psychology is the introduction of a comparable approach into psychology. It requires us to turn momentarily away from the study of behavior. The problem with studying behavior is that it comes to us too much ready-made in terms of our common-sense experience. Our position in regard to it is the same as Newton's would have been had he set out to formulate laws for the common-sense observations about the ways people, apples, and objects in the sea fall. Clearly, these different categories of objects do not fall in the same way in terms of our common-sense experience. As almost everyone knows, people fall because they are "stimulated" to do so by such things as stepping on banana peels, while apples must fall for a different reason, since they aren't "stimulated" by anything, and everything falls much slower in the sea than over the land. Therefore, Newton's laws to explain these different types of events would have had to be separate and unrelated, if he had limited his theorizing to common-sense experience. And, of course, the study of planetary orbits would not have entered into it anywhere, since that was regarded as an entirely different subject matter, not even involving "falling."

Behavior usually has been defined in terms of everyday common-sense, experiential categories. Rats eating food, chickens pecking on knobs, people saying "I like this," "I don't like that," and so on. No wonder that so often when one investigator sets out to replicate the results published by another, he or she can't restrain himself or herself from improving slightly on the procedures: there is so much variation anyway in activities conforming to the same operational definitions.

If Liddell was right, back in the 1930s, that the relationship between experimenter and subject can exert considerable influence on what the subject does, then what does it mean for two investigators to say they are using an "operationally defined variable" by, for example, reading the same set of instructions to two groups of subjects? What about the human context? Better yet, what about the possibility that different purposes consciously or unconsciously held by different investigators will influence their findings? How uniform is it, really, for each one to read the same words to two groups of subjects, each in his or her own way?

Liddell's old misgivings have come back to haunt us recently in Robert Rosenthal's (1976, 1977) view of "experimenter bias" as an "unintended determinant of experimental results." Rosenthal (1977) demonstrated that interactions between experimenter and subjects must not be left out of consideration, if you want to understand fully the results of an experiment. One of his demonstrations, quoted in a text on experimental psychology, shows how different an "objective" experiment looks when you see it as part of a larger system. Rosenthal reports:

> We told half of our student-experimenters that they had "maze-bright," intelligent rats; we told the rest that they had the stupid rats. Naturally, there was no real difference among any of the animals.... The rats believed to be bright improved daily in running the maze—they ran faster and more accurately—while the apparently dull animals did poorly....
>
> Then we asked our students to rate the rats and to describe their own attitudes toward them. Those who believed they were working with intelligent animals liked them better and found them more pleasant. Such students said they felt more relaxed with the animals; they treated them more gently and were more enthusiastic about the experiment than were the students who thought they had dull rats to work with. Curiously, the students with "bright" rats said they handled them more but talked to them less. One wonders what students with "dull" rats were saying to those poor creatures. (Myers, 1980, p. 160)

As you begin to get acquainted with the control-theory model in the next three chapters, you might want to think back to this report, and raise it to a higher level of analysis. Don't you wonder what Dr. Rosenthal said to each of his groups of students? (That is, what might have been his intentions in designing and running his experiment? How might they, too, have affected the outcome?)

Perhaps, then, "behavior" is not what we want to study in psychology. It is not exactly "mind," either. A book review in the journal *Science* was titled with the question, "What is a living organism?" (Potter, 1968) The book reviewed was by a biologist: *The Organism as an Adaptive Control System* (Reiner, 1968). If you accept this view of organisms, including the human organism, then the psychology of an adaptive control system would be the study of what it controls and how it works as it does so. Humans control their environments. But that definition is circular, because when you ask what is an environment, you get back to what humans control. However, looking deeper into the question, we find that the aspects of their environment which humans control are determined by the variables which are detectable by the human sensory receptors, and the computations which their higher-order systems can make upon them. Thus, the study of psychology must include the variables which humans can detect, their combinations in higher-level perceptual variables, and how we control them, to whatever degree of complexity we can define. Behavior of every sort consists of combinations of such variables. But in the way it is studied currently, it often involves random slices through the combinations of controllable variables, rather than being pinned to the actual way in which the nervous system is organized to control such variables.

If we shift our primary goal as psychologists to understanding how *control* works, then several subsidiary goals, related to our conduct as scientists, also will be changed.

Rosenthal's study of "experimenter bias" might be considered to involve a social system composed of several individual systems, each acting to realize its individual purpose within the environment created by their collective interactions. Instead of demonstrating a "principle" of human behavior (named "the self-fulfilling prophecy"), the "experimeter bias" described by Rosenthal might be interpreted as a situation in which rats, students, and teachers all were acting to meet their own purposes or *reference signals*, as they variously construed them. The reference signals of the students then might be understood as purposes or intentions to perceive that "smart" animals learn faster than dull ones. (And hence their own conscious and unconscious actions would tend to realize those expectations.) The reference signal of the researcher would have been to perceive "experimenter bias" on the part of the student experimenters, and the reference signal of the rats would have been to get fed, by whatever means they could.

After presenting the control-theory model, we shall consider further its implications for changes in the way in which to study psychology in the future. One of the immediate results, we believe, will be to help cure the kind of problem about which personality researcher Seymour Epstein complains in an article on "the stability of behavior." He begins his article by stating:

> Some years ago Koch (1959) concluded that there was a resistance of psychological findings to empirical generalization. Unfortunately, the situation has not improved today. It is becoming increasingly evident that we are rapidly approaching a crisis in research associated with extremely inefficient procedures for establishing reliable generalizations. Not only are experimental findings often difficult to replicate when there are the slightest alterations in conditions, but even attempts at exact replication frequently fail. (Epstein, 1980, p. 790)

According to Epstein, the tremendous difficulty in obtaining findings which hold up consistently over different groups of subjects and different laboratory conditions (in traditional psychological research) can be explained as follows:

> The dominant paradigm in psychological research consists of conducting laboratory experiments in which independent variables are manipulated and the effects upon dependent variables observed, while all relevant incidental sources of influence are presumably controlled. At face value, it seems that this model should be as successful for the social sciences as it has been for the physical sciences... adequate control in the social sciences is often impossible because of the extreme degree of situational specificity of much human behavior.... (Ibid.)

We disagree with Epstein that the "model" used in the social sciences has been like that typically used in the physical sciences. Powers (1973) has argued that the so-called "models" heretofore proposed in the social sciences have *not* been models in the sense meant in the physical sciences. That is exactly why this book is being published—to introduce one, finally, in psychology.

In the next chapter, we shall introduce, as new objects of psychological study, the controlled condition and the properties of the controlling system. We offer these alternatives to "behavior" as objects of investigation. "Behavior" was defined as the object of study in an attempt to copy the methods of the physical sciences, as Epstein pointed out. But a major flaw in the logic was overlooked. The physical sciences developed as studies of phenomena which are not control systems. Chemical reactions, falling bodies, levers, etc. will behave exactly the same whether or not someone is attempting to find out how they behave. They are not feedback systems and have no purposes. A number of psychologists have begun to realize the difference that makes, although they do not say it that way, since they are not speaking with a control-theory model in mind. We remind you again of Liddell's (1944) remark that the relationship between a trainer and an experimental animal constitutes a system which cannot be ignored in understanding what is being observed in the experimental situation. Robert Rosenthal's (1976) observations about "experimenter effects" in research make the same point from a slightly different perspective. Psychological research will be different when we understand that the condition a research subject attempts to control cannot be identified without identifying the subject's and the experimenter's purposes in relation to each other.

Although Behaviorism also could be said to be interested in how organisms work, two problems have emerged in its approach, one theoretical and one practical. The theoretical problem is that Behaviorism began by cutting the link between what is happening in the nervous system (or better, in the organism as a whole) and what the person is doing in the "real world." D. O. Hebb (1949), in his pioneering book *The Organization of Behavior*, struggled with this problem. His Introduction illustrates that struggle: "It might be argued that the task of the psychologist... [is] *the task of understanding behavior and reducing the vagaries of human thought to a mechanical process of cause and effect....*" (italics added). He appears to be equating behavior and thought, or at least considering them subjects to be dealt with on a par. Further along in the Introduction, Hebb says:

> The central problem with which we must find a way to deal can be put in two different ways. Psychologically, it is the problem of thought: some sort of process that is not fully controlled by environmental stimulation and yet cooperates closely with that stimulation. From another point of view, physiologically, the problem is that of the transmission of excitation from sensory to motor cortex.

In the very act of trying to bring these problems together, Hebb continued to separate them, because he was working within assumptions which themselves were the cause of the problem. If the sensory cortex is "activated" by energy from outside the organism, then what activates the motor cortex? Not external stimuli, also. Then does the sensory cortex "stimulate" the motor cortex to respond? To answer this question with a yes would violate the previous definition given to the concept of stimulus-response, in which "stimulus" has to be an *environmental* force. The problem is in perceiving the sensory and motor cortices as two "things" to be related with each other, rather than as aspects of a unified system.

The practical problem, closely related to the above, as we now see, was that stated by Epstein (1979, 1980) in his articles on "the stability of behavior." (That is, on the *instability* of it.) How can we make predictions about behavior if the general principles which we try to formulate prove to be unreliable? Epstein raises the question: "How serious a limitation is imposed on psychology as a science, if general laws cannot be used to predict particular instances of ordinary behavior?" He attempts to answer this question by an analogy to the case of the physicist who can state important laws about the behavior of gases without being able to predict the "behavior" of individual molecules. The analogy is not helpful. No one cares what an individual gas molecule is going to do next. But clinical psychologists, for example, would give a lot to know with high reliability the likelihood that a single person making a suicide threat is likely to carry it out. It might be that the probability of carrying out a suicide threat could never be estimated accurately beyond the predictions which skillful clinicians currently achieve. That might be because the outcome is determined by a host of events which have not yet occurred when the threat is made. But if that is the case, good theory ought to show why it is so.

As things stand now, much effort is being expended to derive reliable "laws" of behavior which stand up under rigidly controlled laboratory conditions —which still cannot be translated into formulations helping us to understand the real behavior that finally is most interesting to us. Instead of trying harder and harder to find more reliable generalizations about external forces which "cause" behavior, we at least should consider whether the problem might not be that behavior does not lend itself to precise generalization. Instead, there might be some other concept meeting this objective far better. In that case, the aim of psychology should be to frame and test such an alternate model. We begin to do just that in the next chapter.

Notes

1. It is important not to confuse this observation with the justification often given for performing an investigation under laboratory conditions. Laboratory conditions, however artificial, should not alter the basic nature of the phenomena under study, if they are to be worth anything. We shall return to this issue later, as we see how modern ethology and psychobiology have raised misgivings similar to those aroused in Liddell by his work in the 1930s.

2. Ultimately, physical phenomena such as electromagnetic or sound vibrations.

Foreword to Part 2

Here we introduce the new theoretical model underlying the paradigm revolution in psychology discussed in the first two chapters. It will require actual work with the model to discover what we mean by saying that it is a radical alternative to the cause and effect model, which is the one used by psychologists in the past.

What we mean by working with the model is that it is necessary to examine some quantitative examples to understand it fully. That is probably the only way to get free of the *cause and effect way of thinking*—in which things necessarily happen one after the other—and to learn to think in terms of several things all happening at once, with each affecting the others simultaneously.

You will be given illustrations in the form of actual behavioral performances allowing you to experience control directly, as did the exercises in Chapter 2, but going a step further in being analyzable quantitatively. You will be surprised at how your understanding of the way behavior really works will be enhanced as you seriously work through the demonstrations.

All of the computations necessary will be provided, with no steps skipped, so you should be able to follow them without getting lost *if* you do your part, which is to *do the calculations for yourself*. It is easy to assume that, since the numbers are provided in tables, you don't have to work them out. This is a common mistake of people who think that they have no aptitude for mathematics, and it can become a self-fulfilling prophecy. One can no more build in the habits of quantitative thinking by simply looking at examples of it than one can learn to talk by simply listening to other people.

Part 2

The Control-Theory Model

Chapter 3

What Is Behavior?

3.1 Introduction

It might seem that after a history of over 120 years, the science of psychology would have a crisp answer for the question heading this chapter. It does not, and that fact is behind most of the theoretical difficulties which have held psychology back. Behavior is a catchall word meaning almost anything you want it to mean. It can mean anything from tensing a muscle to solving a differential equation, from jumping after a pinprick to despairing after getting your bank statement. Behavior (in the life sciences) is simply everything that any organism can be seen doing. This definition is so nebulous, philosophers of behavioral science can't even decide whether falling down an elevator shaft is a behavior. This is why theory in psychology is in such poor shape: how can we devise a theory of *everything* which happens?

In the attempt to bring order into this enormous variety of phenomena, psychologists have tried to simplify it by using generalizations—observations which, while somewhat vague, can be applied to many instances of behavior differing in detail. But generalizing, while it can give us an illusion of understanding, becomes less useful as it becomes more successful. In order to generalize, we have to ignore observations, to say that things are the same which are *not* the same, to proclaim that all men are mortal and ignore the fact that they can be mortal in immensely significant yet different and even contradictory ways. We are forced to treat classes of human beings as if all individuals classified in the same way are in fact the same. We are led to say that human behavior has certain properties even when the experiments behind these statements actually show that 30, 40, 50, or even 60 per cent of the subjects in those experiments did not have those properties. The more we generalize about human characteristics, the more falsehoods we utter.

When a physicist proposes a "general law" for the behavior of matter, what is meant is something quite different from what psychologists have meant by a generalization. In physics, the term "general law" means a law which applies generally: all of the time, in every case, with no exceptions whatsoever. If this criterion were applied to the laws of behavior which have been found in the life sciences, we would have to conclude that *no* general laws of behavior have been found. To arrive at laws of human or animal behavior which are general in the sense meant by a physicist, it is clear that we will have to go about the whole project in a new way.

After the above remark that behavior includes phenomena of unlimited variety, it may strike the reader as foolish if we now claim that the biggest problem in understanding behavior has come about from not looking at it in enough detail. There *are* truly general laws of behavior, but to see them, we must resist the temptation to turn immediately to the more interesting aspects of human existence, and focus instead on some humdrum and picky details of just how behavior is brought about. You may be surprised at how much we can learn about behavior in general by ignoring the Big Picture for a while, and concentrating on a few simple and obvious facts—that is, facts which are obvious once they are called to your attention. Let's start by looking in detail at a behavior which may seem to be already about as detailed as anyone would wish: moving a finger.

Make a fist with your index finger extended straight out. Move the finger as far up, then as far down as it can bend at the main joint, keeping it straight. We're going to try to understand how you do that.

This finger movement would be accepted by almost anyone except a determined obstructionist as a very simple example of motor behavior—about the simplest possible. If you were asked how you operate an elevator button, you could answer, "By extending my forefinger and making it press on the button." But if you were asked how you extend that forefinger as you would have to do before pressing the button, how would you answer? There isn't anything else you have to do first; you just do it.

One kind of answer can be found if you use your free hand to grasp the forearm (over the top) at the widest part, holding it fairly tightly while you move the straight forefinger up and down. You will feel a muscle tensing as the finger moves up (strain it upward as far as it will go or you won't feel anything), and relaxing as it moves down. This muscle is attached to bone at one end and to a long tendon at the other end. The tendon runs along the top of your hand and pulls on the bone of the forefinger just above the joint; that's what makes the finger rise. If you make a fist and squeeze hard, you'll feel muscles on the underside of the forearm tensing; there are also muscles in the hand which help. You will find that you can feel these muscles tensing and relaxing without using the other hand: you can feel the efforts directly.

Obviously, the finger is not moving itself. It is being moved by something else: the muscles in the forearm, mainly. So when you say you are moving the finger, don't you really mean that you are tensing the muscles which move the finger?

This ought to raise some questions in your mind as to what you mean when you say, "I move my finger." Whatever it is which you do, you *don't* do it to the finger: you do it to a muscle. The finger does whatever the muscle makes it do; it's just a padded bony lever, a physical thing which has to do whatever the applied forces make it do. If your hand were grasping the knob of the shift lever in a car, you might say, "I'm moving the shift lever," but you're not doing anything to the shift lever directly. You're doing something to your muscles, and they are making the hand and arm move, which in turn make the shift lever move. The movement of the shift lever is an outcome of what your muscles are doing: a *consequence*, just as the movement of your forefinger is an outcome of what the muscle you feel is doing.

Now give some thought to a question which will sound silly at first, and try to answer it seriously. How do you know you are moving your forefinger? What is the evidence? How do you prove it to yourself? Most people probably would answer that they can see the finger moving and where it is at each instant, that they can feel its position (even with their eyes closed), and that they can feel effort in the forearm muscles (once that is brought to their attention). Anything else? How about changes in skin pressure where the joint is? Anything else?

Whatever your answers may be after a careful and close examination, there will be one answer you will not give. You will not say, "I feel the nerve signals which make the muscle get tense."

All of the evidence you can find is sensory evidence. You see and you feel the finger's position. You see it because light reflected from the finger enters your eye, and because sensory nerves in your retinas send a report inward toward your brain. You feel it because sensory nerve-endings in your joints, skin, and muscles are stimulated by the muscle tension and its consequences, and because the nerve-endings send signals up your arms, up your spine, and into your brain. There is no other way for you to know even that you *have* a forefinger, much less what it is doing.

When you say you're moving your finger, what you really mean is that you are experiencing sensory signals coming inward toward your brain from eyes, muscles, joints, and skin. You don't experience the nerve signals travelling from your brain, down the spinal cord, and out your arms into the muscles. Nothing you're experiencing comes from something moving outward. Experience consists of *incoming*, not outgoing, information. It's all input, even the parts of behavior such as muscle tensions which you would think of casually as output.

This is very strange, because when you look at any of the other five billion people on earth wiggling a forefinger, you don't see their inputs, their sensory experiences: you see their outputs, consequences of their muscle tensions. You see a picture of the finger which is different from what they see, and you don't feel what they are feeling at all. The only way you can guess at what they are really seeing and feeling is to wiggle your own forefinger and assume you're built the same way they are. You are the only one on earth who experiences all of what is happening (by way of sensation) when you move your own personal forefinger.

If all you know of your forefinger consists of sensory information coming inward to your brain, what then do you mean by saying, "I'm moving my finger?" What could you possibly mean but "I'm making the sensations of a moving finger occur"? And if you then were asked how you do that, what would you answer? You have turned all of the possible "hows" into sensory evidence for something happening, and you are left with... nothing. The only honest answer to "How do you move your finger?" is "I want it to move, and I immediately see and feel it moving." If there is an explanation for how you do this, it must rely on processes which nobody experiences either from inside or from outside. That is why we need a theory of behavior even to understand our own simplest actions.

Long ago, psychology got itself into trouble with a method called "introspectionism." An introspectionist would try to understand things by looking for private subtle nuances of experience which accompany ordinary behavior. That is *not* what we are doing here. We certainly are emphasizing the personal point of view, but we are turning our attention to the world of experience, not to the world of imagination. We are looking at things which anyone can see with eyes wide open and attention on what is obviously happening. So, if you have heard that introspection is taboo in psychology, you can be sure that by following the reasoning here, you will not become contaminated.

3.2 How We Behave

When we walk, we can feel our legs moving and the muscles which operate the legs tensing rhythmically; we know that the forces applied to the leg bones are holding us up, making us lean forward, and saving us from falling with each forward step. These movements of the legs and body are outcomes of muscle tensions, but they are not outcomes of muscle tensions alone. The muscles supply forces which swing the legs at the hips and knees, and prevent the knees from buckling. They have to do this because there are other forces, just as large, acting on the same bones. The weight of the body always is pressing down; the momentum of the legs and trunk tends to keep every movement going in its original direction until some force alters the movement. Under normal circumstances, the footing changes from one step to another, and wind can push in any direction on the body; if the direction of movement is to continue unchanged, the muscle forces must alter appropriately. Every part of the body is involved in walking, muscles twisting and bending and swinging various parts to keep the body upright and balanced, despite shifts in the center of gravity, and despite loads we are carrying and disturbances coming and going without warning.

The muscles accomplish all of these results by pulling on the sides of bones, which are jointed end to end, and so offer almost no mechanical stability by themselves. If all of the muscles relaxed, we would slump into a heap, like one of those Halloween skeletons which stands up when you pull the string at the bottom, but collapses when you let go. The very act of standing erect is an outcome of what muscles and gravity, combined, do.

When you hold out an arm to point at something, the muscles of the arm are not exerting a force in the direction of pointing; their net force pulls the arm straight up, not forward, canceling the force due to gravity. In general, the forces created by muscles are hardly ever applied in the same direction as the result we observe. Usually, they are at some angle to the resultant net force. They even can be applied *opposite* to the resultant; when we walk downhill, the net forces in the legs are directed so they would move us backward on level ground. When you lower a bucket on a rope, you are pulling upward while the bucket is moving downward—gravity is pulling just slightly harder than you are.

So even the motions and postures of our own bodies can't be thought of as simple effects of muscle action. Many forces are acting as we stand and move, and muscles contribute only a portion of the total forces. It is the total force, the net result, which moves us, not just the muscle force. Enlarging the picture, we can ask about the kinds of behavior involving actions in an independent external world, rather than just movements of the body or the carrying of loads. Consider the shift lever. Few people would object to calling "shifting into neutral" a behavior. We can see people doing this all of the time, over and over, quite reliably. We can study the circumstances under which they will do this—when stopping at a red light, for example. We might even suppose that somehow the sight of the red light is causing the driver to shift into neutral, because there is clearly a cause-like appearance to the sequence of events. So, carelessly, we might start thinking about a causal chain running from the senses (the eyes) to the muscles which do the shifting, and then think we have explained the behavior. This is a careless conclusion, because it requires the red light to know what gear the car is in before the shift, and to alter its effects on the driver accordingly. In a car with four forward gears, there are four positions in which the lever might be found when the car is in gear and moving toward the stop light. The muscle action to shift from first gear into neutral is different from the action to shift from any other gear into neutral. Shifting into neutral can require a force up and right, down and right, up and left, or down and left. There is no simple way to connect the eyes to the muscles which provides all the different directions of force required to make the lever end up in the neutral position.

There is no way the the brain can issue a command to the muscles saying "shift into neutral." In general, there is no way the brain can issue a command to the muscles saying anything like "lift the suitcase" or "adjust the temperature" or "cut down the tree" or "drive to work." While such activities certainly qualify as behaviors, carrying them out is not a matter of reeling off some preset sequence of muscle tensions. The suitcase might be filled with bricks or feathers; the temperature might be too high, too low, or just right; the tree might be a spindly sapling or a huge redwood; and driving to work using the same movements one made yesterday undoubtedly would result in a wreck.

The muscle actions which will accomplish particular behaviors are not predictable in advance, either by an outside observer or by a brain. Obeying a request to produce the same behavior, such as "hand me that balloon," can call for exactly opposite muscle actions under different conditions, depending on whether the balloon is full of helium or water. Even when the direction is the same, the amount of muscle action required can vary from one instance to another of "the same behavior," as in opening doors or chewing steaks or taking another drink from a glass or untying a shoelace. These variations arise because the patterns we call behaviors do not depend *only* on muscle tensions: making the same pattern occur again and again requires muscle actions to be just as different as the independent forces and resistances which are acting and the independent behaviors of other objects which are present when the behavior recurs.

The psychologist William James understood this problem 100 years ago. He said that the hallmark of life is the achievment of repeatable ends by variable means. Somehow, this staggeringly important observation was shrugged off by the behavioral scientists of his day, and most of those who followed. Most "scientific" explanations of behavior continued to rely on the supposition that if we account for muscle tensions, we have automatically accounted for the observable regular consequences of those tensions. Nobody seemed to realize that if the muscles repeat their patterns of tension exactly, there would be little chance that the resulting pattern of behavior is the same as before, or even close to it. The normal assumption even today is that if a pattern of behavior repeats, the muscle tensions which brought it about, and the neural commands sent to the muscles, also must have repeated. If you have been following the examples here, you will realize that that is virtually impossible.

The way we behave is *not* to generate specific patterns of muscle tension having specific consequences. It is to make specific consequences result from *whatever* muscle tensions are required in the immediate circumstances. Behaviors are not muscle actions, but *consequences* of muscle actions. We reproduce *outcomes*, not efforts.

3.3 Perception and Action

The conventional interpretation of behavior puts the cart before the horse —one possible arrangement, but not the only one, and probably not the best one. It begins with the assumption that behavior is caused by what happens to an organism, starting through its senses. With that concept firmly in mind, a scientist naturally would assume that there is some kind of cause-effect chain running from the sensory nerves, into the brain, out to the muscles, and outward from there to observable patterns of behavior.

If we were thinking of science as some ideal of intellectual purity, we might expect any scientist who began with the cause-effect idea to abandon it as soon as the problems we have been noticing were discovered. But that is not what has happened. What happened is that influential scientists said, "Well, we know that input causes output, so there must be some way in which the output depends on the input in a regular way, even though it doesn't appear to do so. When our research has progressed enough, we shall see that this is true." And "knowing" this, they proceeded to analyze behavior as if the causal chain were exactly what they imagined it to be. Evidence to the contrary was set firmly aside—there *had* to be something wrong with it.

One important consequence of this act of faith was to encourage scientists to interpret sensory phenomena as eliciting, causing, or guiding behavior. Having settled on this role for sensory effects, they became blinded to another fact about perception which is just as obvious, but doesn't fit the same picture. Sensory phenomena depend on behavior, too (cf. Smith and Smith, 1973, p. 5). Suppose for a moment that we think of muscle action as being caused in some way, inside the organism, which we cannot yet explain. What are the sensory consequences of muscle actions? Once you see it this way, many answers offer themselves. Consider the simple act of looking at something. If we thought of visual effects as causes, we would say that the presence of objects stimulates the eye, causing the brain to change the direction in which the eyes are looking. But if we reverse the interpretation, it is just as easy to say that by altering the direction in which the eyes are oriented, the brain alters the image on the retina. Then, looking at something means using the muscles of the eye to bring the image of that something to the center of the retina, where we can see it in more detail.

Anything you do with your body can be understood in the same way. You can't make a move without drastically affecting the sense of effort, position, pressure, and velocity you receive from sensors liberally scattered throughout your body. When you take a step, you create a feeling of compression in the bottom of your foot. When you move your hand to an object, you create a sensation of touch in your finger. When you use your arm in a certain way, you can see a forkful of food rising; you can feel it entering your mouth, experience the taste and other sensations which the food creates, and feel the chewing and swallowing efforts. When you use your diaphragm and vocal muscles in a certain way, you can feel your mouth and tongue moving, and hear sounds which you recognize as words. When you write a letter, you see, feel, and hear the pencil scratching over the paper, and you see a pattern of loops and lines appearing where the pencil has moved; you recognize these forms as written words, or perhaps as drawings. When you make your arm reach out to grasp a knob on the television set, you see it, feel the effort, hear the little click, and find yourself watching a picture on the screen.

Of course, your senses report many things happening which are *not* affected by your muscles. If they don't concern anything which matters to you, you just experience them. If they do matter to you, but you can't affect them with your muscles, you still just experience them, although you may wish you could act to alter them. If there is something going on which you can affect and which you think needs affecting, you act with your muscles to change what is being experienced. That's the only reason you *ever* act.

It is perfectly possible to take action as the primary fact of behavior, and to see sensory phenomena as depending on action (to the extent they relate to action at all). Doing this forces us to take a point of view from *inside* the behaving organism, since the external point of view doesn't include the experiences which the actions are affecting in the other organism.

Of course, we can see the outward results of another organism's actions, and we can understand them as experiences of our own, as the appearance of the other's behavior from our own private point of view. But we can't see what it is about the action or its results which matters to the other organism. If we accept the outward appearance of behavior without being aware of our own roles as perceiving and interpreting entities just like the other organism, we are likely to misinterpret what is going on, thinking that what we find interesting or significant about the consequences of action is the same as what the acting organism finds interesting or significant. Any act has many visible consequences, but we can't assume that all the consequences we observe also are observed by the other organism, or have any importance to it, or signify the same thing to the other which they signify to us.

With a little practice, you could become so adept at interpreting sensory phenomena as consequences of action that this would begin to seem the only reasonable view. But if mere familiarity and self-persuasion were the only reasons you had for looking at behavior in this way, you would be no better off than those who hold the other view for similar reasons.

Suppose someone asked you, "How do you explain the way you jump when someone pops a paper bag just behind your head? Isn't that sound making you jump? Are you claiming that you jumped before you heard the sound, or that you made the sound happen in some way?" If you were utterly convinced that action causes perception, you might reply, "Well, I don't see the answer right away, but I know that action causes perception, and some day when we know more, I am sure the answer to your question will come out right."

"Come out right" means "support my belief." Is this what science comes down to? Is it just a matter of inventing a plausible interpretation of what we see, then defending it and excusing (or ignoring) its faults? Unfortunately, much of the time that is exactly how science is understood and conducted. But we don't have to be satisfied with that concept of science; nor have the major thinkers in the life sciences been satisfied with it, even though they settled for the view we are rejecting, warts and all. There is more to scientific justifications than defending clever verbal interpretations.

No fact in science stands by itself—there are always alternate explanations for any isolated fact. Most scientists want the knowledge in their own fields to be as consistent as possible with that of other fields (as they understand it). Scientists who "saw" that sensory phenomena cause behavior maintained this view in part because everything they knew about the physical sciences said that the natural world simply works this way: one event causes the next event. Looking around them at devices produced by the technology of their times, the founders and early pioneers of the life sciences saw (almost, but not quite exclusively) cause-effect systems. Technology embodies what we understand of the way nature works; there is nothing in most machinery to suggest that the causal picture is wrong. So the view that makes behavior an effect was not just an arbitrary belief; it seemed to be the only belief which would not contradict the findings of other sciences which were, in fact, doing much better than the life sciences were doing in achieving results. If there were some contradictions left over, they presumably would be cleared up by progress either in the life sciences or in the others.[1]

While most psychologists reject out-and-out machine analogies as ways of explaining the behavior of organisms, they nevertheless always have used the ideas behind technology as their frameworks of explanation. The material devices invented by engineers don't matter; what matter are the concepts of organization, logic, and relationship underlying the specific machines. Those concepts represent the best which the human race has been able to do with respect to understanding nature. Of course those concepts are used by life scientists: how could they not be used? To say that nerves conduct information to the brain as wires conduct electricity is not to say that nerves are wires. It is only to say that the same principle is involved, and to reject other possible principles such as the idea that the nerves are tubes carrying fluid pressures to the brain, or that the brain knows about the outside world by some means which doesn't involve the conduction of information through nerves. All things considered, the decision to assume that behavior is caused by sensory stimulation was completely reasonable. The only alternative, that the brain spontaneously creates action, found no backing from any other branch of science. What would you have done, knowing only what early life scientists knew about nature? If you were honest, you would have done exactly the same, not to defend a faith, but to defend science itself.

There are really two views of behavior we have to consider, each with its positive points, and each with seemingly fatal flaws. One is that behavior is caused by sensory impacts on the organism. The other is that behavior consists of internally generated muscle action (or equivalent) with the sole purpose of acting on whatever aspects of sensory input can be altered by behavior. The first view ignores the fact that the presumed causal chain at the output actually doesn't exist. The second view leaves behavior totally unrelated to external events, while we can see that it *is* related to them, sometimes very systematically and predictably.

This is a fundamental conflict of ideas, the kind of conflict which always has preceded scientific revolutions. Chemistry truly began with the question of whether something was absorbed or given off during combustion: a simple matter of direction. For 150 years it was believed that escaping phlogiston causes combustion. Then it was proposed that a substance from the air actually is absorbed instead. Both propositions were supported by evidence, both were considered plausible by their proponents. The discovery of oxygen (by the chief proponent of phlogiston!) settled the matter. Similarly, modern physics began with an impossibility: the observation that the measured velocity of light doesn't depend on how fast either the observer or the source was moving. The old idea that light moves like a wave through a medium called, charmingly, "the luminiferous ether," required the velocity to depend on at least the motion of the observer. A series of scientists, whose work culminated with Einstein, showed that to bring the truths of Newton into congruence with the truths of experimental physics, we had to revise our fundamental concepts of time and space.

Now we have another such situation. There are two lines of thinking, culminating in two completely opposed interpretations of the nature of behavior. There is evidence on both sides, convincing to the proponents of each view. Both views fail to answer all of the questions which can be raised, serious questions. And, as always before, the resolution which is now coming to light is the result of discovering a new principle. There is indeed a relationship between perception and action. But neither one is the cause of the other.

3.4 The Advent of Control Theory

Human beings always have been fascinated with gadgets accomplishing something by themselves—devices apparently behaving spontaneously, rather than because of visible external causes. There always have been inventors who constructed the equivalent of windup or battery-operated toys. Most such inventions, however, were not as clever as they seemed, because once set in motion, they could do only what they had been constructed to do, regardless of circumstances. The toy robot seems to walk in a human manner, but it will continue walking until its battery runs down, even though its face is against a wall. Scattered throughout history, however, there have been a few inventions of a different sort: devices which can alter their actions in response to disturbances, so as to keep something under control. Mayr (1970) has reviewed devices like this dating from the 3rd century B.C. until the 19th century, and Bennett (1979) has carried the story into the 20th century. These devices are called control systems.

The story of the *theory* of control systems really does not start until the morning of August 2, 1929. That is when H. S. Black, a Bell Laboratories engineer riding to work on the Lackawanna ferry, suddenly understood how negative feedback works. All preceding control systems had used negative feedback, but Black's insight made it possible to build a theory of negative feedback, a systematic way of understanding it and designing machines using it. Black found the basic principle which developed, during the following 10 years, into control-system engineering.

Long before Black, however, there were scientists who saw that there is more to behavior than just responding to stimulation. In the middle of the 19th century, Claude Bernard, a French physician, wrote a landmark book in which he called attention to the way organisms manage to maintain their own internal environments steady in spite of the multitude of disturbances tending to alter them. To Bernard, it was clear that organisms stabilize the physical and chemical variables which are essential to the maintenance of life, actively opposing any external influences which might change the state of the organism away from the optimum state. There were also many scientists who swam against the mainstream of scientific opinion by insisting that the behavior of organisms—at least human beings—is purposive, goal-directed, intentional. We really can't count most of them as part of the story, however, because they had no defensible reasons for maintaining this view. They were simply voicing common sense. There are always scientists who seem to want to stay ahead of the crowd by grabbing up any new idea and running with it before they understand it, hoping that if others prove the idea right, they can claim to have known it all along. These scientists do little to advance knowledge, because they are wrong more often than right, and avoid the hard work involved in testing a new idea. (And if they happen to get lucky, they can be insufferable!)

But here and there were scientists who were working slowly toward the right idea. In the 1890s, William James and John Dewey presented what evidence they had. Dewey even saw that the "reflex arc" had to be treated as a single organizational unit, not as a sequence of causes and effects. In the early 1930s, around the same time Black published his idea, Walter B. Cannon wrote *The Wisdom of the Body,* in which he showed in detail how the body stabilizes its temperature, blood chemistry, and other critical variables. Cannon suggested that the same principles might apply to human behavior in general, and even to societies. One of his students, Arturo Rosenblueth, later joined Norbert Wiener in founding cybernetics, which was based specifically on the new concepts of control-system theory.

From Black's discovery to the opening stages of World War II, in a rapid series of developments, engineers analyzed the way human beings acted to control many different kinds of variables, and began building machines which could do the same thing. These machines acted to control what they were sensing. Unfortunately for the life sciences, the engineering approach was highly mathematical, and not in the least slanted toward helping anyone understand the behavior of organisms. To make matters worse, the prevailing opinion in the life sciences was that no system made of matter actually could behave in the way control systems in fact do behave. The old causal view was so firmly entrenched by the mid-1930s that most life scientists had become literally incapable of grasping how control systems really work—even scientists who tried to do so.

Time after time, a psychologist or a biologist would attempt to apply control theory to conventional science, only to find that the new ideas were strangely at odds with the facts of nature, even though working examples existed. And time after time, the concepts of control theory were wrestled into a form consistent with what was believed about causation in behavior, destroying their meaning completely. This was not done deliberately. It was done simply in the attempt to make sense of control theory in terms of another theory with which it happens to be totally incompatible. After you have learned the basic concepts of control theory, you should look through the life science literature of the 1950s and 1960s to see how narrowly, but thoroughly, the correct concepts were missed. And when you begin writing on this subject, you should remember that there will be students 40 years in the future reading what you now so bravely insist is the truth.

There is no need for a student of the life sciences to learn the mathematical theory of control systems as an engineer should learn it, although doing this would be far from a disadvantage. The basic principles can be learned without the mathematics. There are certain basic relationships, certain ways of analyzing behavior, which make sense by themselves, and can be applied correctly in their own terms. Control theory is a subject which can be learned at many levels; how far you go with it depends on your interests and your curiosity about why certain relationships work as they do. The full-blown subject is not to everyone's taste. But serious work with control theory requires at least collaboration with someone who understands the mathematics and the practical applications of the theory. This subject can get as complicated as you like, but if all you want is to *use* control theory, that is perfectly possible, and no disgrace. There may be times when you have to take the word of someone who understands the theory more deeply than you, but is there anyone who doesn't have to do that in some field?

As a way of leading into the subject of control theory, let's try to establish a new way of seeing behavior, which will make the task easier. A good part of learning control theory consists of *unlearning* other ideas which don't work as well, and of looking at behavior with a more critical eye than the conventional approach teaches us to use. There is a systematic way of looking at behavior, similar to the "means-ends analysis" proposed years ago, which raises all of the right questions and leads quite directly to the right answers.

3.5 Parsing Behavior

When we parse a sentence, we break it down into its functional parts: subjects, verbs, modifiers, phrases, and so on. We can do the same with behavior. Starting with the usual informal way of describing a simple behavior, we can parse it into a consistent set of elements which (almost) always can be found in it.

The first step is to pick some simple and common behavior which we normally describe with a word or brief phrase: let's use "frying an egg." Such phrases actually do not describe any human action: we must first recognize that we are talking about a *consequence* of an action or set of actions. If I hand you an egg and tell you to "fry" it, you will find that you can't do that with any effort you know how to create. You can hold the egg in your hand, but you can't fry it in your hand. Frying isn't an action; it's a result of an action.

Now we know we are looking for two different kinds of things: a set of actions, and a set of consequences of actions. The frying of the egg has to be put among the consequences. The actions required are clearly things like getting out a frying pan, greasing it, turning on the flame, cracking the egg, and letting the insides run gently into the frying pan. Those are actions we can perform (try not to leap ahead of the reasoning, please: yes, those are consequences, too, but they are controllable consequences, and we can call them actions). It is up to the hot frying pan to fry the egg.

Having separated the actions from their results, we can put them aside for the time being. Let's look at the results in more detail.

The next question to ask is how the consequence of interest will change as a result of our action. The egg can exist in at least two states, raw and fried. Our action is going to change it from one state into the other. If you ever have fried an egg for someone else, however, you will know that this is too crude a distinction. What one person considers "fried," another considers "cooked to destruction," and a third considers "revoltingly raw." We have to think of the state of the egg in terms of some variable attribute which can change over a whole range. Probably the concept of "runniness" would be adequate for this simple example. The raw egg is as runny as it can get; the longer the egg cooks, the less the runniness, until finally it isn't runny at all: an "overcooked" egg, according to some people.

In short, we define a *variable* aspect of the consequence, and, if we can, a variable capturing the essence of what is being done. We substitute the attribute of "runniness" for the either-or term "fried," thus bringing in the idea that this behavior involves a continuously variable consequence instead of just a category that either exists or doesn't exist.

Now that the consequence is a variable, we can specify the particular state of this variable at which we shall say the behavior is accomplished: the state of runniness in which the egg can be categorized as fried. When a *specific degree* of runniness is seen, we turn off the heat and slide the egg onto a plate. There is a subtle corollary of this idea: if somehow we found the egg in the pan already in this state, we would immediately turn off the heat—we wouldn't do anything to the egg, as it already is fried mysteriously to the specified degree. We can, in fact, define this particular state of the variable as the *desired* or *specified* state—the state which we would take no action to change.

That is an operational definition of what is called in control theory the *reference level* of a controlled variable. The term "level" indicates degree or amount. We also could say "reference state," or in this specific case, "reference runniness." The reference level of a variable is the position of that variable along its range of variation at which *no action* will be taken to change its value, magnitude, or state. (Think of the range of variation indicated by the numbers on the dial of a thermostat.)

We now have separated the action from its consequence, and have converted the consequence from a category into a variable; we also have specified the reference level of the variable, the state of the variable at which action to change it should stop. The final step in parsing this behavior is to look at the relationship between the actions we set aside and the variable representing their consequence. We want to focus on just the action or actions immediately relevant to bringing the variable to its reference level. Obviously, getting out an egg and a frying pan, greasing the pan, turning on the flame, and breaking the egg into the pan are all essential preliminaries, but they all would be done the same way, no matter what reference level was chosen for runniness. Let's peel away all of these actions, which are just preliminaries, and look only at the one action directly affecting runniness: turning the flame to a given height for some variable length of time. We turn the flame on, wait, and turn it off.

Now the question is, how are the acts of turning the flame on and off related to the variable, runniness? From the egg's point of view, the runniness depends on how long the flame is turned on, however it gets turned on. As time goes by, with a constant flame, the egg becomes less and less runny. If the flame is set high or the gas company is using a high-energy fuel, the runniness will decline more rapidly than it will with a low flame, low-energy fuel, or both. There are all sorts of unpredictable combinations of factors which would make the runniness decline at various rates. But most combinations of factors sooner or later would get the egg to the reference level of runniness.

The change in the variable depends on the action according to factors which convert a twist of a knob into a rate of heat delivery, and the heat delivery into a rate of polymerization of the protein in the egg. The effect of the action on the variable is independent of what made the action occur—a person, a machine, or spontaneous combustion. But from the actor's point of view, none of the factors affecting speed of cooking matters much. The actor simply turns the flame on if the runniness is greater than the reference level, and off when the runniness reaches its reference level. No timing is required, no watching of the height of the flame, no estimation of the calories per second being delivered to the egg, no organic chemistry. The action depends on the variable in a very simple way: while the runniness is greater than its reference level, turn the flame on or leave it on; when the runniness reaches the reference level, twist the knob to "off."

If you like, you can introduce a second dimension into this process: crispness. An egg fried slowly will be uniform when it reaches the reference-runniness; one fried very fast will be crisp and brown on the bottom when the same runniness is reached. By listening to the sizzle and adjusting the height of the flame accordingly, an experienced cook can deliver an egg with both a specified reference level of runniness and an independently specified reference level of crispness. Adjusting the sizzle variable to a reference level produces a predictable amount of crispness. This predictable amount actually would be adjusted as part of a larger system which has been making small adjustments of the reference sizzle for a long time, using many eggs, finally arriving at (and storing in memory) an amount of sizzle which produces the reference crispness. So we have a hierarchical control system (and a phenomenon which some have called, mistakenly, "feed-forward").

But we're not mentioning control systems yet, much less hierarchies of them. What we have done here is to parse a behavior into the essential action, the variable it affects, the reference level for that variable, and the two ways the action relates to the variable (how the action affects the state of the variable, and how the state of the variable affects the action). Everything in this parsing is easy to understand, except for one thing: the reference level. At this moment, we can't explain why there is a reference level or what determines it. But by defining it operationally as the state of the behavioral variable at which action on that variable ceases, we have made it as observable as anything else. Explanations can come later.

When you parse behavior in this way, you have prepared for analyzing it as a control process. Also, you have avoided most of the traps making a simple causal model *appear* to work by omitting critical details. It is therefore a good idea to get some practice at this parsing, and that would seem a good way to end this chapter. The following is an outline you could use as a checklist:

I. The informal word or phrase.

II. A. The actions.
    1. Preliminary or invariant actions.
    2. Action which affects the variable.
    3. How the action affects the variable.

B. The consequences.
  1. Irrelevant side-effects.
  2. The variable that is affected by the action.
  3. The reference level of the variable.
  4. How the difference between the variable and its reference level affects action.

Try using this outline to parse these behaviors: putting five gallons of gas in a car; sharpening a pencil; aiming a gun at the bullseye; throwing a ball; raising a flag; balancing your checkbook.

Here is an example showing how we can break down a fairly complex behavioral sequence, and then parse each part of the behavior as a control process. Table 3.1 shows only the basic parts of the analysis.

Table 3.1 Control actions involved in preparing to back a stick-shift car out of a driveway

Behavior	*Action*	*Variable*	*Reference*
open door	grasp, pull	angle of door	80 degrees
get into seat	bend, sit, slide	configuration	seated
shut door	grasp, pull	angle of door	zero degrees
fasten seatbelt	push ends together	distance	zero distance
adjust mirror	grasp, twist	image position	centered
depress clutch	leg push	position	down
insert key	extend arm	key-lock distance	zero distance
start engine	twist	sound of engine	whir, vroom
shift to reverse	grasp, push	lever position	reverse

Learning to take behavior apart in this way is only the beginning of a control-system analysis. All we have so far is a way of generating plausible possibilities. If you compare your way of parsing with someone else's, you might find that there is more than one way to do it—there might be different ways of seeing the essential means, different definitions of the important variable, different but equally good ideas about the reference state and the relationships of action to the variable. Coming up with a plausible analysis is only the starting point. Of course you have to have a starting point, and it is even preferable to have more than one starting point in mind. That is because the next step in analyzing the behavior is to *test* the way you have parsed it. This step is, unfortunately, almost always left out when people come up with plausible ways of seeing or explaining behavior. It's easy to say that a little girl hit her littler brother because of sibling rivalry. But how would you go about proving that this is the correct explanation? It's not enough to say that if something called sibling rivalry exists, little girls will hit littler brothers. You can't use the observation you're trying to explain as proof that the explanation is right. What you need is some other way to test for the existence of sibling rivalry, some way that doesn't depend on looking at siblings doing things which look like rivalry.

If that isn't clear, try a more familiar example. Suppose your car starts to buck and falter. Your companion says, "Oh, too bad, you have fouled spark plugs." When you ask how your companion knows that, the answer is "That's exactly how cars with fouled plugs act." You could argue back with a different theory: no, it's probably the tank of gas you got at a sleazy-looking gas station where they probably water the gas. The car is acting just like a car burning gas with water in it. You both could go on like this for hours, citing past experience and insisting that what is wrong is probably this or probably that, and using the *very same behavior* of the car to "prove" that your explanation is right.

Well, how do you settle such an argument? How do you test any of these theories? It's very simple. If you think that a fouled plug is causing the problem, you get out of the car, lift the hood, remove a plug, and look at it. That's a test which does *not* depend on using the same effect you're trying to explain. It's a lot more trouble than sitting inside the car out of the rain and arguing with words, but if you decide you're going to accept only explanations which can be tested independently, you will go ahead, get wet, and find out that in fact the spark plugs are wet, too.

To explain human behavior, we can't open the hood and look at the plugs, but at least we can do better than offer glib strings of words and use the observations they explain to justify the explanation. All we really need is a test which could come out either in support of the explanation or against it. Observing the car can't falsify the theory that the gas is bad because the car is running erratically —it won't suddenly stop running erratically to disprove the hypothesis, and if it did smooth out, we could explain that the water passed through the engine and the rest of the gas is good. You can't lose! If you think of a proper test, you *can* lose. That's the kind of test we need to find out whether we have parsed behavior correctly, or have chosen the better of two different ways of parsing it. We need a test that's simple, easily reproduced, clear-cut in its results, and doesn't depend on assuming the very propositions we are testing. There is such a test which we can devise using the principles of control theory: it's called "the test for the controlled variable." Before we can see how to apply that test, we have to develop the basic concepts of control theory. That is what we shall do in the next chapter.

Notes

1. From the conventional standpoint, there were serious problems with accepting the view that action is the primary factor in behavior. The most serious was that an inner cause of behavior seemed to be totally unpredictable. If behavior were caused from inside an organism, why wouldn't it just be "capricious"? How could we then explain the cases in which behavior seemed to be related in systematic ways to external events? We can, in fact, find regular relationships between behavior and independent aspects of the world outside the organism. Most of the time, these relationships are shifty and unreliable, but once in a while a clear-cut phenomenon is seen, as in the example of bursting a paper bag behind someone's head.

So, early psychologists reasoned that if some behavior could be explained clearly in terms of external events acting on the senses, why not all of it? Why mix two entirely different kinds of explanation for the same behavior? If we have one explanation which sometimes works very well, what could a second one, based on unobservable processes inside an organism, add? [Eventually, that line of thinking resulted in Behaviorism, in which no processes inside the organism were considered fit subject matter for psychology. (RJR)]

Chapter 4

The Basics of Control Theory*

4.1 Introduction

In the previous chapter, we began by asking about an exceptionally simple kind of behavior: moving a finger. In this chapter, we're going to analyze an even simpler behavior: holding something still. We'll be examining "the rubber-band experiment" from Powers (1973), a demonstration of control theory which makes clear all of the visible relationships of control. One great advantage of using this demonstration is that anyone can afford the equipment needed to set up the experiment and try it out. One small warning—you will find this chapter tough going if you read it without a couple of rubber bands at hand to help make the relationships clear.

4.2 The Rubber-Band Experiment

To do the rubber-band experiment, you need two rubber bands. Pull each one's end through the other so they become tied together end-to-end. In a two-person experiment, one person is the subject and the other is the experimenter. The subject takes hold of one end of the rubber bands, the experimenter takes hold of the other, and the two people stretch the rubber bands slightly, just above the surface of a table. The task which the subject tries to carry out is to hold the knot exactly over a mark on the table while the experimenter moves the other end of the rubber bands. If the table top is featureless, make a spot on a piece of paper. For our purposes here, let's suppose that the people agree to keep the rubber bands lying in one line running from left to right between them, so rotations about the spot don't come into the picture. You can do this experiment two-handed, letting one hand be the experimenter and the other the subject, just to see the relationships.

The rubber-band experiment illustrates some basic feedback relationships which can be found in many examples of ordinary behavior. The position of the knot represents something in the environment which you can perceive; the rubber band between your finger and the knot represents the effects your behavior has on that perceived thing. The other rubber band represents a connection

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*We wish to acknowledge the help of Northeastern Illinois University students Rose Marie Elysée, Marcella Oyer, and John Lehman in clarifying the presentation of this chapter. (WTP, RJR) from independent events which also affect the same perceived thing. For example, if you're driving a car: the car's position in its lane corresponds to the knot's position; pulling on the subject's rubber band corresponds to turning the steering wheel. The other rubber band corresponds to the effects of curves, crosswinds or bumps which influence the car's position on the road, just as the steering wheel does. When the wind blows, you see the car start to deviate, and you turn the wheel to reduce the deviation. When the experimenter pulls on the other rubber band, you see the knot begin to move, and you pull on your end to keep it where you want it.

The parallel applies even in abstract situations. Suppose we say that the position of the knot corresponds to your mood. Someone has been criticizing you, making your mood worse, as you perceive it. So what do you do? You "pull on your end of the rubber band"—you start doing and thinking things which will cheer you up. The mood is in the middle: it's affected one way by independent disturbances (the criticisms), and the other way by your attempts to feel better. In fact, you might feel yourself getting into a bad mood and immediately take steps to do something interesting or fun, to keep the mood from changing. That's like pulling on your end of the rubber band before the disturbance on the other end has much chance to move the knot. To someone else who can't feel your mood, it might look as if your actions were caused by the events which threatened your good spirits. Of course, you know that the only reason for your actions was to keep those events from having any important effect on you.

It is important actually to do this experiment with real rubber bands in the real world. If you *do* it, instead of just imagining it, your eyes will show you what is happening, whereas your imagination might lead you to guess something else.

4.2.1 Analyzing the Experiment

First, let's lay out the relationships in the environment part of the experiment. We'll use the method of parsing the behavior in question. In parsing a behavior, we look for the variable which is sensed and the variable which measures action. In this case, the variable which is sensed is the position of the knot, and the action variable is the position of the end of the rubber bands held by the subject. But we now see a new feature: an independent effect on the knot, caused by something other than the action. We call this independent something the ***disturbance***, because it disturbs the position at which the knot is held. We could diagram it, using "d" for disturbance, "a" for action, and "sv" for "sensed variable" (the knot):

d————————sv————————a	start: in balance
←	
d——————————sv——————————a	disturbance moves sv
→	
d——————————————sv——————————————a	action cancels effect

When you do the experiment, you will see that the effect of the disturbance is exaggerated above, because you don't wait for it to have its full effect before you start counteracting it by moving your end to the right. This isn't a sequence of actions, but two almost-simultaneous processes—disturbing and resisting.

The term "disturbance" is somewhat ambiguous; it might refer to the change in the sensed variable, or to the cause of that change. We shall always mean the cause of the change (in this case the position of the experimenter's end of the rubber bands). We can't talk about "the" effect of the disturbance on the sensed variable, because the action affects the variable, too, and can change at the same time the disturbance changes. There might be any amount of effect from the disturbance (including none, if the corrective action changes just as fast as the disturbance).

If the disturbance can be represented by the position of one end of the rubber bands, and the action by the position of the other end, then the sensed variable clearly depends on both action and disturbance. As long as the two rubber bands are identical, and as long as they don't go limp (conditions we assume), the position of the knot will always be *midway* between the positions of the disturbance-end and the action-end.

If we let "d" and "a" be those two measured positions, then "v," the position of the sensed variable, will be equal to (d + a)/2—the average position. We measure from the position of the spot, which we call 0. If the subject end is to the right of the spot, the position of the disturbance-end will be negative, to the left of the spot; so, if the action-end is 6 inches to the right and the disturbance-end is 6 inches to the left, the position of the knot can found by averaging the two end positions: (-6 + 6)/2 = 0. The knot will be over the spot, because the spot is located at the zero of measurement. Figure 4.1 shows these physical relationships.

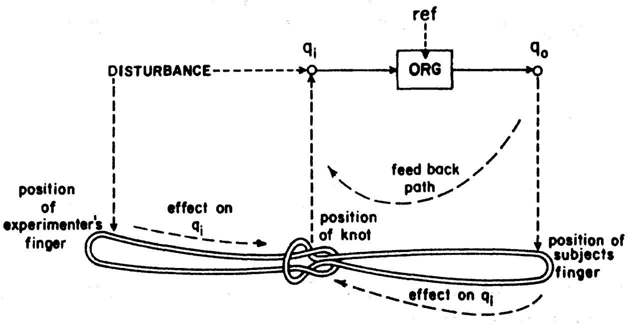

Figure 4.1 The rubber-band experiment [reprinted with permission from: William T. Powers, *Behavior: The Control of Perception* (New York; Aldine de Gruyter) Copyright © 1973 William T. Powers]

If the disturbance-end is held still and the action-end is moved, the knot moves half as much, because the resultant position is determined by the average of the disturbing position, d, and the correcting position, a. Moving the disturbance-end also will affect the knot by half as much, for the same reason.

4.2.2 *Diagraming the Experiment*

We can show these same relationships in a different way by using a block diagram. In a block diagram, the value of every variable is completely determined by the effects shown by arrows that reach it. If you want to include another effect on any variable, you have to draw another arrow and show its source. Variables which aren't affected by anything else are assumed to be independent variables (a and d in this case, so far); you can set them arbitrarily to any values. The point is to account for the values of all variables except the independent variables, by showing what determines their values. Everything that affects the variables must be shown. Figure 4.2 is a block diagram of the rubber-band experiment.

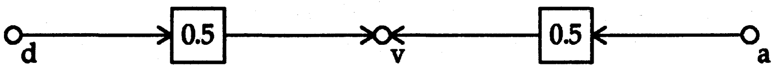

Figure 4.2 Relationships of d and a to v

In Figure 4.2, we see the disturbance-end of the rubber bands as a small circle labeled d, the action-end as a small circle labeled a, and the sensed variable, the position of the knot, as a small circle labelled v. Arrows connect the variables a and d to the boxes, and two arrows converge on v in the middle. If the rubber bands were unequal in length or pulling power, the values of a and d would be correspondingly unequal, but by amounts we could predict from knowing the relative strengths of the rubber bands. For the time being, we assume they are equal.

For example, suppose you are told that the action variable is +6 and the sensed variable is +10. From that, you should be able to figure out what the disturbing variable is. The sure way to do this is to plot positions in space, rather than looking at the block diagram. It's much easier to draw than to say:

```
            a      sv      d
|           |      |       |
0           6      10      ?
```

Here, the disturbance- and action-ends in the physical system are opposite to the way the block diagram is drawn.

The block diagram provides a quick way to find the same result without drawing anything. From it, you can read off the equation v = (a + d)/2, which says that the sensed variable is the average position of d and a. Plug in the known numbers and solve for the unknown. If a is 6, then since (6 + d)/2 = 10, (6 + d) = 20, and the disturbance must be 14. Similarly, if the disturbance is -12 and the sensed variable is 2, the action variable must be 16. The corresponding drawing looks like this:

```
d                      v                a
|                   |  |                |
-12                 0  2                ?
```

Once again: the sum of d and a divided by 2 is 2. Since d is -12, and -12 plus a over 2 is 2, a is 16. Whatever a and d are, there always will be a corresponding value of v which we can compute without knowing anything about the subject. These properties are strictly properties of the rubber bands.

4.2.3 Diagraming the Subject

Now we need to include the person who produces the action. In Figure 4.3, we see a new box; this one receives an arrow coming from the sensed variable, and emits an arrow going to the action variable. This box represents whatever it is about the subject which matters here. Inside the box, we have put the letter k, which represents the amplification of corrective action as it goes around the loop—a number we don't know yet. The output or action variable is obtained by multiplying the value of v by k. (Think of the increase of muscle action as movement begins.) We assume a value of -20 for k for now; it must be negative, for reasons to be made clear later. This extremely simple model of the person leaves out something important, but it will do for the present, since the experiment is set up to compensate for the omission.

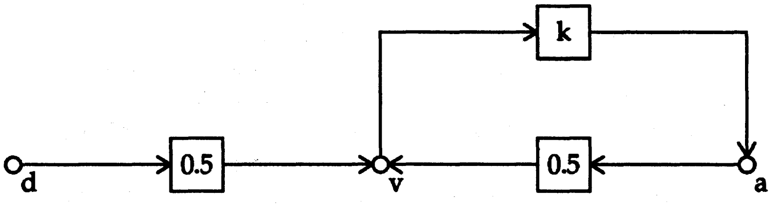

Figure 4.3 Simplified control-system block diagram

Notice that we now have a second relationship between v and a. The first relationship is established by the rubber bands. The second one is established by the action of the person sensing the position of v. The problem now is to discover what sets of values are consistent with *both* of these relationships.

The relationship due to the environment is expressed as $v = (a + d)/2$. The one due to the person is expressed as $a = kv$. There is only one independent variable left, the disturbance. All the others have arrows coming into them, and therefore are totally determined by the sources of those arrows. The arrow running from v into the subject-box represents the path of sensory information about the position of the knot relative to the zero point (where we find the stationary spot on the table). The arrow coming out of the subject-box and reaching the action variable represents a physical effect (of the person's muscles and arm) on the subject-end of the rubber bands. The subject's action completely determines the position of that end of the rubber bands; the value of the disturbance (the position of the experimenter's hand) completely determines the position of the other end of the rubber band. The positions of those two ends completely determine the position of the knot, and the position of the knot completely determines (as far as is shown here) the subject's action and the position of that end of the rubber bands.

4.2.4 The Cause-Effect Fallacy

If you follow the arrows, starting with the one going into the subject-box from the sensed variable, you will end up back where you started, at the sensed variable. This closed circuit is called "the loop" by control theorists. If you think of a change in the sensed variable as a cause, and trace the effect chain once around the loop, you will find that the sensed variable is its own effect. Trying to understand this closed causal circle has led innumerable behavioral scientists astray. You can't understand this closed loop correctly by tracing in the direction of cause and effect around and around the circle. The reason is that effects are amplified as they travel around the loop; when you reason forward, you're unconsciously assuming that these effects happen one after another. Therefore, after just one trip around the loop, you end up where you started with a far larger effect—leading to disaster, as shown in Table 4.1.

The amplification of effects is called the "loop amplification factor" or "loop gain." This factor is the amount by which any small change in a variable in the loop will be multiplied as its effects go once around the loop. We called it k. Suppose that the value of k is 20 (we could assume any value). That means that any small change in v will result in a change in a which is 20 times as large. The variable v is the average of a and d, so if only a changes, v will change half as much. The change in a is multiplied by 0.5 to convert it into an effect on v, so the total multiplication is (20)(0.5) or 10. The loop gain is 10.

In order for this system to work properly, we must have a negative value for k, because a negative (leftward) movement in the position of the knot has to result in a positive (rightward) change of the subject end of the rubber bands, if the knot is to be kept near the zero spot. The corrective action "takes away" from the disturbance, hence we assume k is -20, instead of 20. In control systems, the loop gain must *always* be negative; there can be any number of multiplication factors in the loop, each having either positive or negative signs, but there *must* be an odd number of negative factors to make the total product negative. With k equal to -20, what happens if we trace the effect of a 1-unit change in v forward all the way around the loop? A leftward (negative) 1-unit change in v causes a 20-unit change in a, which causes a 10-unit change in v.* Going around again, the 10-unit change in v causes a negative 200-unit change in a, which causes a negative 100 unit change in v. The following changes in v are 1000, -10000, 100000, and so on. (See Table 4.1.)

Table 4.1 Results of tracing a negative 1-unit change in v clockwise around the loop in Figure 4.3

Step	*v*	*k*	*a [= vk]*	*(0.5)a*	*new v*
1	-1	-20	20	10	10
2	10	-20	-200	-100	-100
3	-100	-20	2000	1000	1000
4	1000	-20	-20000	-10000	-10000

Table 4.1 shows what happens when you try to reason out the behavior of this system in the natural direction, the same direction as cause and effect. If you didn't know anything about closed-loop systems, you might conclude that we have come up with an unworkable design. But that would be a mistake. By reasoning correctly about this system, meaning *backward*, we can show that no such runaway has to happen, even with very large amplification factors.

Why did the system seem to run away? We corrected the sign of the feedback effect, making it negative, but the result was certainly not the kind of behavior we would call "control." Everything looked fine when we looked at the relationships qualitatively—the action opposed the change in the sensed variable—but as soon as we tried out some numbers, everything went to pieces. Should we conclude that loop gain must be numerically less than 1? Not at all. All we have to do is analyze the system correctly. This means reasoning our way *backward* around the system to deduce what its state of equilibrium will be.

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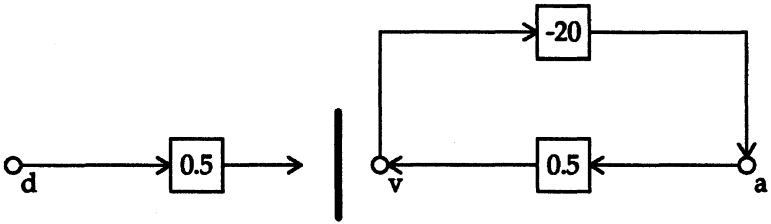
*Because v = (0.5)a, as shown in Figure 4.3.

4.2.5 Reasoning Backward

This is *not* a simulation of how the system behaves, but a way of understanding how all of its variables must be related. Using a systematic method, we can start with a guess about the values of variables, and then step-by-step correct those variables, making them better and better. The final result will show the true relationships among the variables.

When you understand how the variables are related, you can use the model as a simulation for predicting the detailed changes in action which occur as the system counteracts disturbances. We shall do this later. It is most important, however, to understand how there can be a stable state in a system with a high loop gain, because lack of this understanding is the primary reason for the failure of earlier psychologists to make correct use of control theory.

Suppose we assume that the sensed variable has a value of 1 (ignore the disturbance for now, by assuming it to be 0). Then $v = (a + d)/2$, but since $d = 0$, $v = a/2$, and thus $a = (2)v$. According to Figure 4.4, the action variable a must have a value of 2, since, in the forward direction, $(2)(0.5) = 1$.



(this side momentarily disregarded)

(if v = 1, via action of a, then a = 2, but v = -0.1, via action of k on a: ????)

Figure 4.4 Control-system block diagram without d effect

Looking at the subject-box and seeing that the action variable a is -20 times the value of the sensed variable v, we compute that v must have the value of 2 divided by -20, or -0.1.* But that conclusion is inconsistent with our starting assumption that the sensed variable had the value 1—now it's -0.1. This method is set up so that the new value of v is closer to the correct value than our original guess. Therefore, we can use this new value as a new guess, and go through the calculations again. Let's set up a table according to Figure 4.4 and compute our way around it several times to find out how that happens. (Check the calculations in Table 4.2 yourself.)

Table 4.2 Computation of effects of a and k on v, assuming d = 0

Step	*v*	*a [= (2)v]*	*k*	*new v [= a/k]*
1	1	2	-20	2/20 = -0.1
2	-0.1	-0.2	-20	0.01
3	0.01	0.02	-20	-0.001
4	-0.001	-0.002	-20	0.0001

---

*Because (-0.1)(-20) = +2.

If we keep going around, eventually we shall arrive at $v = 0$ and $a = 0$ (exactly). Then we can continue going around, in either direction, and these numbers will remain consistent with each other.

What have we done differently? We have reasoned our way around the loop backward. Furthermore, we haven't asked what will happen after a small perturbation: we have simply asked what values of the variables are consistent with each other. We can't *say* simply that there will be a perturbation; if we want to see the effects of a disturbance, we have to provide a way to introduce a disturbance into the diagram, so its effects can be analyzed correctly. That is why we have a disturbance in the block diagram and in the real experiment. We ignored the disturbance in the backward reasoning we just went through. Let's do the reasoning again, this time taking the disturbance into account—in fact, starting with the disturbance.

Suppose the experimenter pulls the disturbance-end of the rubber bands to the left, so $d = -6$. The subject, we can guess, pulls the other end an equal distance to the right, so $a = +6$. That gives us a beginning guess that v, the position of the knot, $= 0$.

We could guess that $v = 100$ and still arrive at the right answer. Given v, and knowing that $v = (a + d)/2$, we can see that $a = (2)v - d$. Since d is always -6, this means $a = (2)v + 6$. This is the formula we use for deducing a when we know v. If $v = 0$, then a must be $(2)(0) + 6 = 6$. If a is 6, then going backward through the subject, we find that v must be $6/(-20) = -0.3$. This is our next guess. With $v = -0.3$, a must be 5.4 units. And we can keep going around and around, getting closer and closer to the right answer, as shown in Table 4.3.

Table 4.3 Finding the steady-state condition

Step	*d*	*v*	*a [= 2(v-(0.5)d)]*	*k*	*new v [= a/k]*
1	-6	0	6	-20	-0.3
2	-6	-0.3	5.4	-20	-0.27
3	-6	-0.27	5.46	-20	-0.273

... and so on to the final exact answers, $v = -0.272727...$ and $a = 5.454545...$

In other words, a position of the knot about 0.27 units to the left and a position of the subject-end of the rubber band about 5.45 units to the right are consistent with a disturbance which moves the other end of the rubber bands 6 inches to the left, and these positions are consistent with a closed-loop arrangement having a loop gain of -10, distributed in the way we assumed (-20 inside the subject, 0.5 in the environment due to averaging the positions). By reasoning backward, we have in fact found the right answer. Even though the loop gain is far larger (negatively) than -1, we find that the system is predicted to reach a stable final state, meaning that the disturbance is counteracted to keep the knot (almost) exactly at zero, just what this control system is meant to do. (To understand why the values are not perfect, read on.)

You might repeat this reasoning using a value for k of -200 instead of -20. That would make the subject 10 times as sensitive to movements of the knot. Would the subject then respond 10 times as much? No. The subject's effect on the rubber band, measured as a, would go from 5.45 to 5.94 units, a change of only 0.49 units. The position of the knot would change from the old value of 0.27 units to 0.029 units—about one tenth as much deviation. When the loop gain goes up, the deviation goes down. If the loop gain were negative infinity, we would find that v = 0 and a = 6. The knot would be precisely over the spot, and the action-end of the rubber bands would be exactly as far to the right as the disturbance-end is to the left. We call a control system with infinite loop gain an "ideal" control system. It controls perfectly.*

4.2.5 Variations in the Experiment

We have found that this model of the rubber-band experiment predicts that the subject will move one end of the rubber bands to a position which keeps the knot near the spot; while we used only one value of disturbance, it should be clear that the same result will happen, however much the experimenter moves the disturbance-end of the rubber bands. To understand how the model works, it would be a good idea to try it with different values of the disturbance.**

It is interesting to test the effect of using unequal rubber bands. Suppose you add a second rubber band on the subject's side, on the free end. The subject still holds the original knot over the spot. Then the controlled knot always will be one-third of the way from the disturbance-end to the action-end, and the "environment equation" will change to v = (2/3)d + (1/3)a. If we leave k at -20, the loop gain will now be (-20)(1/3) = -6.7, instead of -10. You'd expect the deviation of the knot to be a little greater—about 1.5 times what it was before. The real surprise, however, is what happens to the subject's hand position. Previously, moving the disturbance-end 6 inches resulted in the subject-end moving very nearly the same amount the other way. Now the subject end moves almost twice as much. We give the action half as much effect on the sensed variable, and we get twice as much action. You may find it interesting to put the double rubber bands on the disturbance side and calculate what happens—and then try it out for real to see that this is what *does* happen.

You can ask questions of this model, ask what it actually will do if you make different assumptions about the conditions and the properties of the subject (so far, the k factor is the only adjustable "property"). As you play with the model and with the real experiment, you will begin retraining your intuition, so that all of these relationships begin to seem natural. If you have been thinking in the old cause-effect terms, they at first will appear strange and unnatural. When you start saying to yourself, "Oh, of course, I see that it *has* to work that way," you will be well on the way to understanding control theory.

4.3 Expanding the Model

There is one variation which the model we have right now cannot handle at all. Suppose you're a third party while two other people actually are doing the rubber-band experiment. You lean close to the subject and whisper, "Now keep

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*There is, as you might hope, a quicker way to get the right answer: solve the two system equations simultaneously. One equation is v = (0.5)a + (0.5)d, and the other is a = kd. We shall skip the solution because there is something missing in our diagram, but if you solve the equations with k = -20, you will see that the solution works. It works because the algebraic solution shows the values which are consistent with both equations being true at the same time, for all possible values of the variables. Unfortunately, you also will get an answer if you use a positive value of k. That answer is meaningless if k is equal to or greater than 1, for reasons which can't be understood without learning about differential equations. So remember to use only negative values of k.

**Also try plotting the sensed variable and the action variable against the disturbance over a range of disturbances. You need to plot only two points and draw a line between them, since the relationships are linear.

the knot 3 inches to the right of the spot." If the subject complies, you will see the knot immediately move to the right and stay there as the disturbance changes. As the model stands right now, there is no way to make it do that. This model only can keep the knot over the spot, or near it. It can't make the knot go anywhere else.

What must we change in the model to give it the ability to stabilize the knot in a different position from the zero position? Clearly, we can't change anything in the environment part of the model, because in the real situation, nothing has changed about the rubber bands or their relationships to the knot. We have to make the change in the model of the subject. Doing this requires that we rethink what we mean by the sensed variable. We've been treating it as if it were a deviation from the zero position, which also happened to be the position of the spot. The spot apparently designated the "desired" or *reference* condition. Now, however, we see a different reference condition, and we see that we must interpret the sensed variable as the *distance* between the knot and the new reference value of the spot. Initially, the reference value of this distance was zero, so we didn't have to think about it. Now the reference condition is "knot 3 inches to right of spot," and we realize that any distance could be chosen. Zero distance is only *one* of the possibilities.

When the subject is looking at the actual knot, the knot generally isn't 3 inches to the right—not exactly. It's wherever it is. And that is all the subject sees: the knot, where it is. The subject does not see the knot where it is *supposed* to be. So how are we to get this "should-be" position into the model without pretending that there's something in the environment which we can't actually observe?

We put it in the subject: giving a reference signal value corresponding to a displacement of 3 inches (or whatever). While the subject senses the actual displacement of the knot from the spot, he or she now acts to maintain the *difference* between sensed displacement and reference displacement. We have to modify the block diagram to reflect this, as shown in Figure 4.5.

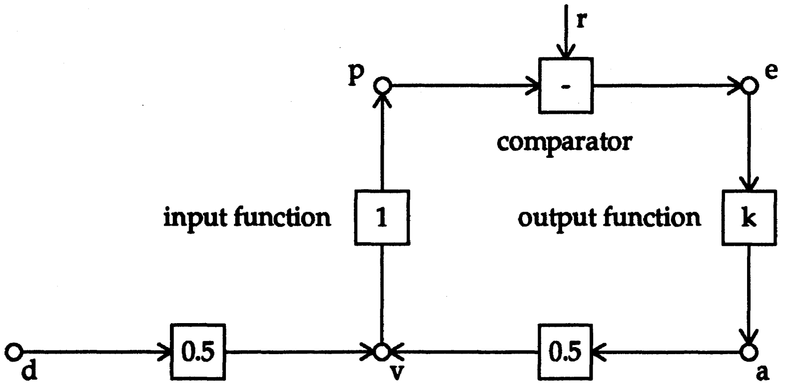

Figure 4.5 Expanded control-system block diagram

Now we have ended the arrow from the sensed variable on a box called "input function." From this box, a new arrow, labeled "p" and called the *perceptual signal*, goes to a *comparator*. (The 1 in the input function simply means that the numerical value of p is the same as that of v—see next paragraph.) A second arrow, labeled "r" for *reference signal*, also ends on the comparator. The source of this reference signal arrow is left undefined at the moment, so this is a new independent variable. In this chapter, we won't worry about where it comes from. Coming out of the comparator is a new arrow, labeled "e" for *error signal*, terminating on a new *output function* box. The factor k is inside the output function box. We have broken up the single subject box into three functions connected by arrows. The arrows are the variables inside the person-part of the model, the control system itself. The boxes still indicate functional relationships—scaling factors or other operations.

We can handle the input function and the comparator in a way which simplifies their use. The input function represents the sensing apparatus of the person. (This includes any neural processing needed to extract information about the specific sensed variable of interest.) The perceptual signal represents the state of the sensed variable in the single dimension currently of interest. In a real person, the perceptual signal is (presumably) a neural signal* representing some equivalent measure of the externally observable variable. We always can pick units for measuring neural frequencies which make the conversion factor in the input function equal to 1, as in "one Nervous System Unit (NSU) per inch."** That fixes the scaling for the rest of the system. The numerical size of the perceptual signal inside the model is therefore always the same as our measure of the observable sensed variable. We can say that $p = v$.

In the comparator, we make the simplifying assumption that $e = r - p$. The magnitude of the error signal is exactly the difference between the perceptual and the reference signal. (It is zero only when the perceptual signal matches the reference signal in magnitude.) Thus, we have normalized the system to a simple form on its input side. All you have to remember is that $p = v$ and $e = r - p$.

Note that we subtract the perceptual signal from the reference signal. This puts a factor of -1 into the loop gain, because a positive change in the perceptual signal entering the comparator comes out as a negative change of the same size in the error signal. That allows us to define k in the output function as a positive number: the negativeness of the loop gain is built into the comparator, as long as all other multiplying constants are positive. Keeping track of signs is much easier if we can let all of the relationships be positive; then there's only one sign inversion to remember, the one in the comparator.

The reference signal is defined in the same units as the perceptual signal, and the magnitude of the perceptual signal is the same as the magnitude of the external sensed variable, although measured in NSU instead of inches (because our model is intended to apply to what goes on inside the head, remember). This means there is a direct correspondence between the setting of the reference signal and the state of the external variable: when the perceptual signal matches the reference signal, the external variable numerically matches the reference signal also. When the external variable is in its reference state, the perceptual signal will match the reference signal. The reference signal determines the externally observable reference level of the sensed variable.

The error signal is multiplied by k to generate the action variable a; the rest of the loop is the same as before. Let's try our backward reasoning again to see the effect of introducing this reference signal.

4.3.1 The Effect of the Reference Signal

Let's see what happens if we set the reference signal to a value of 3 NSU. That,

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*Measured in terms of frequency—impulses per second, for example.

**If a 1-inch displacement results in a signal of 137 impulses per second, we just call 137 impulses per second 1 NSU, and draw the markings on our meters accordingly.

we hope, will define an observable reference condition of 3 inches to the right of the spot. Let's see if it does, using a value of k = 20 (now positive, because of the sign inversion in the comparator). The loop gain is (-1)(20)(0.5) = -10, as before. (Recall that the -1 is to let us use positive values of the other parameters.)

Let's guess that the knot is on the spot: v = 0. Assume also a disturbance of -6 units. For v = 0 and d = -6, it follows that the action variable a must be 6. If the action variable is 6, and k is 20, the error signal magnitude must be 6/20 = 0.3 NSU. The error signal is defined as e = r - p, from which we get p = r - e. The reference signal is 3 NSU, so the perceptual signal is p = 3 - 0.3 = 2.7 NSU. The perceptual signal of 2.7 NSU means that the sensed variable v must have the same magnitude: 2.7 inches (to the right of zero). We shall use this as our second guess.

Let's go around once more. If the value of v is 2.7, and the disturbance is -6, the action variable must have the value of 2(2.7) + 6 = 11.4 inches. That much action variable is produced by an error signal of 11.4/20 = 0.57 NSU. (See Table 4.4.)

Table 4.4 Finding the steady-state condition

Step	*v*	*d*	*r*	*a*	*k*	*e [= a/k]*	*p [= r-e]*	*new v*
1	0	-6	3	6	20	0.3	2.7	2.7
2	2.7	-6	3	11.4	20	0.57	.2.43	2.43
3	2.43	-6	3	10.909	20	0.545	2.4545	2.454

With the a variable = 0.57 and the reference signal = 3 NSU, we find the perceptual signal to be 3 - 0.57 = 2.43 NSU. This value doesn't change much with another pass. The exact value is 2.4545. The controlled variable is 2.4545 inches to the right of the spot, or 0.545 inches to the left of where it should be with the reference signal = 3.

What if we change the disturbance? Suppose we reduce the disturbance to 3 inches, cutting it in half. As you can verify, the position of the knot becomes 2.591 inches. The disturbance-end moves 3 inches to the right, but the position of the knot changes only 0.136 inch (we'll use this number a few paragraphs below). So the reference signal is doing what it is supposed to do: it is determining the position to which the system will bring the knot, and the position at which it will keep the knot, even if the disturbance changes.

You're aware, of course, that the system isn't controlling perfectly, so these statements are only approximately true. But with higher and higher loop gains, they become more and more true. Try other settings of the reference signal and other disturbances to see that this effect continues to hold true: the variable is held near the state set by the reference signal.*

Now we're ready to fulfill a promise made in the previous chapter: to define a test which tells us when a control system is present.

4.3.2 *The Test for the Controlled Variable*

In the previous chapter, we defined the reference level of the sensed variable

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*Note also that if you set d = 0, this does not mean that no physical disturbance acts on the knot, only that you have set the disturbance position to the scale's zero. When the reference setting is not zero, some physical disturbance is still present, because the subject is still pulling to the right, and the knot is to the right of the disturbance position. For the physical disturbing force to be zero, the disturbance would have to have the same value as the reference signal (3 inches, in this case). We ignore the fact that real rubber bands would go slack. "Disturbance" refers to position, not force.

as the state of that variable at which the action of the system would just cease to affect it. As matters stand now, with a disturbance of -6 units, a reference signal of 3 NSU, and a k factor of 20, we have the knot close to the position we calculated, but not exactly at it, and we have anything *but* zero effect of the output on the input, for the subject's end of the rubber band is stretched almost 9 inches to the right of the knot. How could we test this system to discover its reference level exactly?

Let's take a third rubber band and knot it right where the existing knot is. By pulling on this rubber band in the same direction the subject is pulling, we can aid the subject's effort. In effect, by pulling more and more, we can cancel more and more of the physical disturbance. As we increase the pull to the right, the knot (which starts at 2.45 inches to the right) will move more to the right. As it does, the error signal will get smaller, and the subject's amount of pull will decrease. The closer we bring the knot to 3 inches, the less the error signal becomes, and the less the subject pulls. Eventually, we shall be pulling the knot to the right just hard enough to bring it exactly to a displacment of 3 inches. At that point, the perceptual signal will be 3 NSU, which exactly matches the reference signal of 3 NSU, so the error signal will be zero. If the error signal is zero, the action will be zero. At this point, the subject will cease pulling altogether.

There is our operational definition. We don't have to know the setting of the internal reference signal. We simply adjust our pull until the subject's action drops to zero. At that point, we note where the knot is: that is the reference condition of the sensed variable. It will turn out to be 3 inches to the right, as you can verify by trying this.*

The model is our way of explaining why there is a reference condition. If the person really contained a perceptual signal and a reference signal which were compared to create an error signal driving action, then we would see the reference condition at the point where the perceptual signal matches the reference signal. We haven't *proven* that such things exist inside the person. But if they did exist, it would explain what we observe. That's all we ask of a model.

The test for the existence of control doesn't depend on the model. It depends only on the definition of control. Control exists when a disturbance applied to a variable results in a change of action (by the controlling system) which affects the same variable equally and oppositely. In short, the variable is stabilized near a particular state by actions of the behaving system. To see if it really is stabilized, we apply disturbances which would change the variable if the disturbance were not opposed. If every disturbance we can think of (of reasonable magnitude) is canceled by a change in the behavior of the system, we have found a control system.

You can see that our basic experiment with the rubber bands is itself an example of the test. As we vary the position of the disturbance-end of the rubber bands, we would predict that the knot would move half as much in the same direction if the subject-end didn't move. A 3-inch movement of the disturbance-end to the right, as noted above, should produce a 1.5-inch movement of the knot to the right, if the other end of the rubber bands doesn't move. What we found instead was a 0.136-inch movement of the knot to the right, so that the amount we expected the knot to move, assuming no control, was 1.5/0.136, or 11 times as much movement as that which actually did occur.**

How can this test *dis*qualify a variable, showing it is not under control? To

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*It will be *exactly* 3 inches if the subject estimates perfectly or has a scale on which to pick a position.

**That number is exact. It is the loop gain + 1. If you measure the ratio and subtract 1, you have the loop gain (without its minus sign).

see how the test can reject a variable, let's use the case with a string of three rubber bands, two of them on the subject side, so the subject is controlling the knot nearest the disturbance-end. As the disturbance-end moves, the subject's hand moves the other way, twice as much. Because the controlled knot remains essentially still, the other knot moves about half as much as the subject's hand moves. The hand moves twice as far as the disturbance, so the second knot moves by the same amount as the disturbance, in the opposite direction.

If the hand remained still, the second knot would move one-third as much as the disturbance-end moves, in the same direction. We can see immediately that the loop gain for this second knot would have the wrong sign for the assumed model, but ignoring the sign, we still can calculate the ratio of expected to actual movement. The expected movement (with no control) is one-third of the disturbance movement, the actual movement is equal to the disturbance movement, and the loop gain we calculate for the correct knot is 16 times the gain we get by assuming the other knot is under control. That's an easy choice.

The subject could, of course, switch to controlling the other knot. In that case, the test would eliminate the knot formerly under control, in favor of the one next to the subject's end.

When you do this experiment with two people and real rubber bands, be sure the experimenter makes all movements very slowly, and holds each position long enough to see the result (and measure it with a ruler). If you do that, you will be able to make some estimates of the loop gain. What you observe, with the subject actually controlling, is a movement of the knot which is far smaller than the no-control estimate (which you can measure by stretching the rubber bands yourself). It is *so* small, you may have trouble estimating its size.

4.3.3 A Remark about Disturbances

You will have noticed that when we apply test-disturbances to a knot, we don't simply seize the knot and move it to another place. We have defined our system as a system of variables which depend on one another in particular ways. The variables come to states satisfying all relationships at once. To take hold of one dependent variable and arbitrarily change it would violate the relationships which define the system.

If we simply postulate a change in a variable without modelling the means by which the change is brought about, we shall be postulating a change which could not happen with the model organized as it is. Therefore, whatever effect we think we are deducing will be spurious: that is not what would happen if we made the change occur by physical means. This is why we apply disturbances through a rubber band even in the model, and not just by claiming that one of the variables has changed magically. The only exception is an independent variable whose state doesn't depend on anything in the model.

4.4 Choosing between Explanations

We ended the previous chapter by discussing how explanations often are given without any way of testing to see which is the better one. We've given only one explanation of the rubber-band experiment here, the test for the controlled variable being used to help us choose between definitions of what is being controlled. But how could we use the test to distinguish between the control-system explanation and another which doesn't use the concept of control?

One possible alternative explanation is that the subject senses the movement of the experimenter-end of the rubber bands and moves the subject-end the same amount in the opposite direction. This is a stimulus-response explanation, and it would seem to fit the facts just as well as the control-system explanation. If the subject moved one end in response to movements of the other end, the knot naturally would remain still (with equal rubber bands). So the stability of the knot would not indicate control, but simply the natural outcome of two opposing effects.

In the stimulus-response explanation, all that matters is the response to the stimulus: the position of the knot is irrelevant. It would be easy to eliminate the knot from consideration by putting up a cardboard shield allowing the subject to see the ends of the rubber bands, but not the middle. We can even encourage this explanation to work by telling the subject to act as a stimulus-response system: "Move your end of the rubber bands oppositely to the way the other end moves." The subject could certainly do that, while we measured the results behind the shield. Without any test to settle the question, we could say that the movements of the hands are consistent with the stimulus-response explanation. The knot remains nearly in the middle, the hands move oppositely. So the observed phenomena would fit either the control explanation or the stimulus-response explanation. That being the case, it wouldn't matter whether we used the shield or not. Let's dispense with it, so we can say we really are comparing two explanations of the same observation.

But now let's use the test for the controlled variable, by introducing a new disturbance. We fasten a rubber band to the knot, and apply disturbances to the knot by pulling left and right by varying amounts. What do the two explanations predict about the result? According to the stimulus-response explanation, the position of the knot is determined by the way the subject responds to the position of the other end of the rubber bands. However the subject responds, the knot remains midway between the ends. Therefore, if we disturb the position of the knot, we should not disturb the response to the stimulus, and the knot should move.

According to the control-system model, disturbing the knot will alter the error signal and thus alter the action. If we pull toward the subject's hand, that hand will move toward the knot; if we pull the other way, the hand will move away from the knot. By pulling in different directions, we can make the hand move in a way that is far from equal and opposite to the movements of the other end of the rubber bands. What actually happens, assuming that the subject is trying to hold the knot in a particular position, and is not responding to stimulation by movements of the other end? The knot, despite the disturbance applied directly to it, remains essentially in the same place, and the subject's hand moves. The "equal and opposite" response almost disappears.

This seems to settle the question, but it doesn't—not yet. The S-R theorist can claim that now the subject is responding to the movements of rubber bands, the original one and the new one used as a new stimulus. We must be more thorough, by eliminating factors which are necessary to support the S-R theory, while leaving the control-system theory still viable.

The control-system model works by sensing the position of the knot, and does not rely on any inputs indicating the positions of either end of the rubber bands. Therefore, if we use a shield with a hole in it to hide the two ends, leaving only the position of the knot visible, we would expect control to continue as before. We still would expect the ends of the rubber bands to move symmetrically when there is no extra disturbance, and we could predict how the extra disturbance would affect the subject's hand. The S-R model now would have no basis for predicting that the subject's end would move symmetrically with the disturbance-end, because neither end is visible. The third rubber band used for disturbances could be fastened to one side of the knot, so it, too, would be entirely invisible. The S-R model could predict no relationship between that "stimulus" and the subject's hand position. We would observe that the knot remains stabilized as before. Try it. The only recourse the S-R theorist would now have is to claim that the position of the knot is the stimulus in this new situation, even though it is also an effect of the response. At that point the control theorist could smile and say, "Exactly."

Chapter 5

A Hierarchy of Control

5.1 Introduction

Let's go on just a little further with the rubber bands, before getting into more interesting subjects. We analyzed a situation in which the subject was controlling the separation of the knot from the spot, keeping it at 3 inches to the right. To model this action, we had to introduce a reference signal against which the perception of separation was compared. If you tried the reasoning-backward method using a high loop gain, such as 200 or 2000 (the range of actual loop gains you could measure), you found that the knot was kept at this reference separation from the spot-quite accurately, regardless of the amount of disturbance. Starting here, we can bring in a new aspect of the experiment which leads to a new kind of control system.

5.2 Motion Control

If the reference signal gradually changed, at a given moment the knot still would be held at a distance from the spot which corresponds to the setting of the reference signal. You can observe this effect if you do the experiment again, playing the part of the subject while someone else acts as experimenter. Just start the knot about 3 inches to the left, and make it move slowly and smoothly to a position 3 inches to the right. While this is going on, the experimenter should vary the pull on the rubber bands, increasing and decreasing it. There will be some effect on the smooth motion of the knot, but not much—if the experimenter doesn't take this as a challenge and move so much and so fast that you have difficulty keeping the knot where you want it. If the experimenter seems determined to have an effect on the knot, explain what you're trying to do.

As you move the knot slowly to the right, you will notice two things going on at the same time. First, you're moving your end of the rubber band so the knot is where it should be all during its movement. This requires that you sometimes pull more and sometimes pull less—your hand doesn't move the way the knot does, because of the disturbance. You can't make the knot stay still or move smoothly by holding your hand still or moving it smoothly. If you tried that, the changing disturbance would make the knot move very irregularly. The second thing you're doing is making the position of the knot change in a specific way: a smooth slow motion toward the right. You know how the motion *does* look and how it *should* look, and you vary your action to keep the error of motion small.

This is, of course, very confusing. You're not doing anything much different from what you do when you're holding the knot still against a varying disturbance. You can see and feel the average position of your hand increasing to the right, but the actual position is changing both right and left as the disturbance changes. You're not consciously working out all those moves in detail; they're just happening. About the only thing you can claim to be doing in a consciously planned way is wanting the knot to be moving slowly to the right, which it is obligingly doing (give or take a few wobbles). This kind of experience is enough to take you back to childhood, when you asked adults how come you could make your arms and legs move just by thinking about them moving. If you got any answer, it probably wasn't satisfactory.

Suppose we assume that keeping the knot in one position involves an inner organization such as the one we developed in the last chapter. To make the knot move to a different position, you then would suppose that you're changing the reference signal for that control system. That control system sensed position, and compared the position-perception with the reference signal. Could this same control system control motion? No, it could not. It's a position control system, as we designed it.

In order for a control system to control motion, it would have to sense motion, compare the actual amount of motion perceived with some reference amount (slow or fast, left or right), and adjust the rate of change of hand position accordingly. We need a different kind of control system to control motion. We can get a strong hint about what is needed if we imagine that the reference signal for motion is set to zero. What would create zero motion, if we also had a position-control system? A constant position reference signal. Then, if the motion reference signal were set to some positive value, the required motion could be created by producing a constantly increasing reference signal for the position-control system. So we can see that if the motion-control system acted by adjusting the position reference signal, we could have both kinds of control going on at once.

We need a two-level system. The motion-control system must sense motion. We might start all over, and say there is a different way of sensing the knot which reports only its motion and ignores its position. This would require a new kind of sensor responding directly to rate of change of position. We have, however, only one set of eyes. Each and every thing we sense about the knot comes in through the same light-sensitive retinal nerve cells. What we're really talking about are two ways of extracting information from the same basic stream of visual information. One way yields a signal standing for position, the other way a signal standing for rate of change of position.

To be most parsimonious, we can say that there is a second perceptual function at work, receiving the information already standing for position, and responding to the rate of change of that information. In other words, the velocity-perception signal is derived in the brain from the rate at which the position-perception signal changes, not through another process which starts all over in the retina with the original optical image. That proposition needs to be checked experimentally, but since nobody has done that yet, we shall tentatively assume that it's true. If it weren't true, we would have to reorganize the model somewhat, but the basic concepts wouldn't change.

Figure 5.1 shows a two-level model which is able to control the rate-of-change-of-position by altering the reference signal entering a position-control system.

The higher-order input function receives a copy of the position signal, the same signal which enters the lower-order comparator. In the higher-order input function box is the symbol "d/dt," which is mathematical shorthand for "derivative with respect to time," meaning nothing more than "rate of change." In this box, we assume that there is a neural computer responding only to the rate of change of its input from below, ignoring the actual size of the position signal (just as the speedometer on a car indicates the spin rate of the speedometer cable, which also is turning the dials showing the distance the car has moved).

So a positive magnitude of the velocity ("vel") signal indicates that the position ("pos") signal is changing in the positive direction (speeding up), and a negative "vel" signal indicates that the "pos" signal is changing in the negative direction (slowing down). If the "vel" signal is zero, the "pos" signal has stopped changing—the actual position could be anywhere at that moment.

The higher-order output function box is labelled "integrator" (symbol ∫). A constant positive error signal entering this box produces a continually increasing output, meaning a continually increasing reference signal for the position control system. If you apply backward reasoning here, you will find that when the position is moving at a certain rate to the right, there must be some positive error signal, and hence some difference between the sensed velocity and the reference velocity. If the output function is very sensitive to small error signals, the difference between reference and perceived velocities will be very small. You don't need to understand derivatives and integrals now; such subjects would be part of an advanced course in control theory. The general idea will suffice.

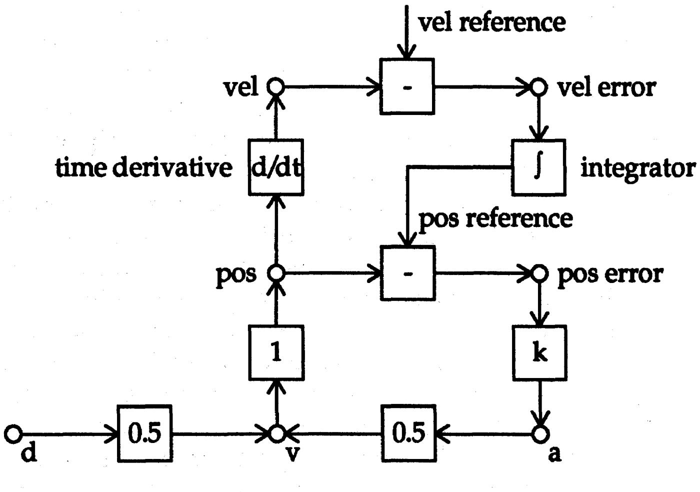

Figure 5.1 Two-level velocity-perceiving control system

There are other ways to model what is going on. To choose one possible model over others, we would have to check the models' behaviors by computation, to see if there are implications of each conceivable arrangement which would show up under different experimental conditions. Sometimes, however, we can eliminate possibilities in a simpler way. We could, for example, interchange the two systems.

If we assumed that the lower system controls velocity, and that the velocity-perception is summed over time to create a position signal for the higher system, we would find that velocity control is impossible: the overall system would always move the knot to a specific position and keep it there. The higher system would vary the velocity reference signal not to achieve a particular *velocity*, but to achieve a particular *position*. So the model wouldn't be able to move the knot at a slow smooth speed; that doesn't *prove* that the picture in Figure 5.1 is right, but it does eliminate a picture in which we interchange the kinds of variables controlled at the two levels. The reason we've set up this two-level model is to illustrate a general principle of hierarchical control, not to argue that this is the right way to model the behavior.

In Figure 5.1, we see a higher-order system which derives its perceptual signal from the perceptual signal in a lower-order system, rather than from sensors connected to the external world. Inside the higher-order system, we have the familiar arrangement of a perceptual signal and a reference signal entering a comparator, and an error signal coming out of the comparator to drive an output function. But now the output function is not creating physical behavior; it is setting the reference signal for the same lower-order system from which the perceptual information came.

Taking the point of view of the higher-order system, we can see that "acting" consists of emitting a reference signal for the lower-order system. This immediately causes the perceptual signal in the lower-order system to match the reference signal (because of the action of the position-control system). If the downgoing reference signal is changing at a certain rate, the upgoing copy of the lower-order perceptual signal will be changing at the same rate, as the lower-order control system keeps the perceived position of the knot matching the reference signal. The result will be a certain value of the higher-order perceptual signal, where a given value now stands for a corresponding rate of change of the lower-order perception. So, from the standpoint of the higher-order system, it simply makes its own perception come to the same magnitude as the reference signal it is receiving (from some unnamed system farther up). The fact that it does this by using a whole lower-order control system makes no difference to it. Except for the meaning of the perceptual signal, the higher-order system is just like the lower-order system in its general arrangement.

There are two basic concepts here. One is that there are higher and lower orders of *perception*, the higher orders being derived from the lower orders. The other is that there are higher and lower orders of *control*, in which higher orders act by varying the reference signals entering lower-order systems. The idea of a hierarchy of perception is really part of the idea of a hierarchy of control.

There are two input or perceptual functions in Figure 5.1. The lower one generates a perceptual signal representing a position in space. It requires certain visual equipment and neural computations in order to exist. The higher one generates a perceptual signal representing rate of change of the lower signal; the neural computer deriving rate of change does not have the same properties as the one deriving position. We could not transplant the neural networks from the higher-order input function to the lower-order input function and expect that the lower-order signal would still correspond to position—the operations being carried out are wrong for computing position. So when we think of levels of perception, we also think in terms of different types of computing processes in the corresponding input functions.

Now suppose that in the nervous system there are perceptual processes occurring in distinct levels, and that one particular type of computation takes place in every perceptual input function at that level. That is, in the rubber-band experiment example, we could pay attention to—perceive—position, change of position, and rate of change of position, each being a higher level.

Imagine, too, that these levels extend over all sensory modalities: sight, sound, touch, and so on. In other words, if there is a level at which rate of change is computed, we shall find perceptions corresponding to rate of change of sights, sounds, touches, smells, efforts, and everything else. We're used to thinking of "motion" as something having to do with visible objects in a three-dimensional space, but if you attend to other kinds of sensory experience, you'll find motion-like phenomena in different sorts of spaces. A whistle with steady pitch would correspond to a position which is steady in space. If the pitch begins to rise at a certain rate, that experience is quite like experiencing an object which begins to move at a certain speed. Similar experiences can be found in any part of the sensory world. In every case, the new aspect, the change or transition, would be derived from the same kind of computation, computation of a first time derivative of the underlying variable.

5.3 Interlude

Before we go on, there are a couple of questions you may have been wondering about which can't be answered fully in an introductory discussion, but which most people will ask as soon as a model with more than one level is mentioned.

One is the question of how many control systems there are. The answer is probably thousands, and that may be conservative. There is one control system, for example, for each of the roughly 800 muscles in the body. At higher levels there may be even more at each level, at least for the first few levels, although not all of them would be able to operate at the same time. The hierarchy we are talking about has many systems at many levels, which brings up the next question.

If there are many systems at each level, how do the multiple hierarchies stay separated? The answer is that, in general, they don't. A given system at one level might receive reference signals from many higher-level systems at once, and construct perceptual signals out of many lower-order perceptual signals. Thus, the net reference signal isn't the signal sent from any one higher-order system, and the higher-order perception doesn't depend on just one lower-order perception.

If you go on to further study of control theory, you'll learn how this arrangement quite naturally can allow higher systems sharing many lower systems to control their own perceptual signals with respect to independent reference signals, without any significant interference with each other. If you aspire to that level of understanding, you will have to prepare yourself by learning mathematics, preferably through the calculus, and even better through differential equations.

Additional questions always come up as soon as "levels" are mentioned. How many levels are there? And, hot on the heels of that question, what determines the reference signal for the highest-level system? The answer to the first of these questions is, when you think about it, obvious: there are as many levels in the model as necessary. We do not introduce new levels in order to make the model as tall as possible; we do it only when we observe something which seems to require a new level not already in the model. After we have levels in the model which account for all of the major types of behavior we notice, we can count them. That shows how many levels there are in the model (or will be, when it is reasonably complete). It can't be completed by sitting and thinking about it. We have to do experiments.

The answer to the second question is a little more elusive. The best answer is that we don't know what determines the reference signal for the highest-level system. If there is a highest level, and if it is a control-system type of level, then there will be reference signals, or something equivalent to them. They must be set somehow, by something.[1]

Perhaps this is a good place to point out that scientists sometimes are reluctant to leave questions like the above unanswered, even when the answer is that nobody knows the answer, or even whether we're asking the right question. If that response leaves you with a feeling of unfinished business, that's good. That's what motivates research. Why shouldn't *you* be the one who finds the answer?

In the remainder of this chapter, we're going to concentrate on sketching in some ideas about the levels of control systems which *may* exist in a human being. We'll start, however, with an attempt to make what's coming a little easier to grasp (in some respects) and a lot harder (in others).

5.4 Perception

The control-system model of behavior didn't grow out of analyzing the phenomenon of human perception. It grew out of building working control systems using artificial sensors, electronic circuits, and motors, over 50 years ago. It was in this context that engineers learned how to make electrical signals stand for nearly any kind of external physical variable, and to construct systems which, by acting to control these signals, also control the external variables on which they depend—just as human beings are observed to do.

As artificial control systems became more and more complex, they began to depend not just on sensors generating signals, but on computers combining those signals to create new variables representing more abstract aspects of the external world. Anything which was to be controlled had to be represented as a signal. Electronic computing, both analogue and digital, taught the engineers something we can see as a lesson about perception: no matter how complex an electronic computation, its outcome is always expressed in the form of a new signal. This new signal is, electrically, no different from the signal coming straight out of a simple sensor like a photoelectric cell or a strain detector. Its meaning is not in the physical signal, but in the way it is obtained from other signals or from multiple sensors. Engineers drew no psychologically interesting conclusions from these phenomena of their own making, but those who eventually became cybernetic control theorists did.

If a single kind of electrical signal can stand not only for something simple like light intensity or temperature, but also for more abstract variables like size, direction, curvature, reaction rate, or the efficiency of a manufacturing process, then clearly the signal does not have to resemble the thing it represents. At the same time, however, a complex external situation cannot be represented completely by a single signal. Each independent way in which the external situation might change—each degree of freedom—has to be sensed and represented by one signal, so that a true picture of the external situation can be obtained only by examining a matrix of many signals at once. Of course, once such a collection of signals exists, each one corresponding to a single attribute of the external world, new computers can be added to boil down sets of these signals to single signals standing for still more abstract aspects of the situation: higher-order attributes. Once again, many such signals would be needed to capture all of the different aspects of the world implicit in the previous set of signals, but the new signals now would have still a new kind of meaning.

You can see how, beginning with the engineering techniques of using computed signals based on sensor signals, the cybernetic control theorist could begin to muse about extensions of this principle, and gradually come to see how a brain might represent multiple aspects of the external world in the form of neural signals, even though one isolated signal looks, on a graph, just like any other isolated neural signal—a train of impulses. This is the route by which we arrive at a picture of perception significantly unlike any others which have been proposed before.

One of the well-known problems with thinking of perceptions as inner representations of the external world is that of infinite regress. If the tree you are looking at is represented inside your brain, doesn't that mean you need something to look at that representation of a tree and recognize it for what it is? And if that process also involves representation, doesn't that call for still another recognizer, and so on forever? This is clearly no explanation at all.

However the brain responds to that tree out there, it doesn't do so by making another little tree inside itself. Psychologists long ago used this line of reasoning to "prove" that perception doesn't necessarily occur in a brain. The argument doesn't prove that at all, of course: it only shows that this way of understanding representation is useless. But we have a different way of thinking about representation. Instead of thinking that the entire tree is shrunk down and replanted inside the head, suppose we say that the attributes making up the tree are individually represented as neural signals. Each neural signal, of course, doesn't look like the attribute it represents: it measures that attribute, like a meter reading. A signal representing "green" isn't colored green, but its magnitude indicates how much greenness is present. The frequency of the neural signal stands for the amount of any particular attribute which is present. If one particular signal is derived by some fixed process of computation, then the signal always measures the same kind of thing, the same attribute. As the external attributes change, the signal becomes larger and smaller, depending on how much of one of the attributes appears to be present.

Recent brain research has found some neural signals which appear to behave like this. For example, when a person looks at a straight black line, a nerve cell in the middle to upper reaches of the brain may begin to fire. As the line is rotated to different angles, the cell fires faster or slower. At one particular angle of the line, the cell will fire at some maximum rate, and if the line then is rotated 90 degrees, the cell will not fire at all. So the firing rate of the cell is a measure of the angle of the line relative to some rather arbitrary zero of orientation. (Arbitrarily determined by the brain circuit.)

This sort of work goes slowly because it is difficult, and opportunities for carrying it out with human beings are rare. (These are mostly animal studies, and we should give a thought to the creatures whose lives have been spent rather casually to tell us these things.) But there is accumulating evidence that there are neural signals which vary as visual images vary in some particular respect—and not when they vary in other respects. The "angle" signal doesn't change if the line is moved without rotation to different parts of the visual field. The only attribute of the line which that nerve-signal represents is its angle. Other cells, however, respond to position; they don't respond to angle. So far, the evidence, sketchy as it is, supports the picture of *attribute representation* we are considering here. Neurophysiologists, it should also be mentioned, have not come across any little trees—only signals which could represent an attribute such as "vertical."

Of course, the cells where these signals are measured don't "respond to" angle or to anything else: they are simply the places where all of the preceding perceptual computations are summed up as a single signal, located at the outputs of perceptual functions. Brain research is still far too primitive to tell us much about the actual computations which derive these signals from raw visual input.

Once we see that individual attributes of the external world, both simple and abstract, can be measured and thus represented as neural signal magnitudes, we can begin to understand how complex perceptions come about. A tree has certain simple visual attributes, such as colors, shadings, edges, curves, and roughness. The computers deriving such attributes must receive the outputs of even simpler processes representing various kinds of intensity of stimulation, visual and nonvisual. As those who try to build imitations of human perceptual processes have found, recognizing even these simple attributes can require very complex signal manipulations.

The tree and its surroundings must, at some early stage of perception, correspond to a very large collection of attribute-signals. No one of them is very interesting. No one of them captures much of the external arrangement. All of them together, however, constitute a world made of multiple attributes of some simple kind. At higher levels of perceptual computing, new attributes can be derived, creating (when considered all together) another version of the world—one made of more abstract attributes.

A tree has a location and a shape. A sufficiently complex computer could extract "distance" and "elongation" from the collections of attribute-signals representing the basic color, edge, and other signals. This does not mean that the abstract notion of distance (to pick one attribute) pops into existence as a descriptive phrase, or that there are signals in the brain a certain distance apart. It means that the attribute of distance (between objects) is present only in the form of a neural signal. As the external distance changes, the internal signal changes magnitude, representing more or less of the "distance-ness" attribute. This isn't an attribute just of the tree, but of many objects considered at once.

It's interesting that if you look very carefully at the distance between one tree and another, you will see nothing at all. You get a sense of the distance, but it doesn't correspond to anything about any object. It seems to float in the air between objects. This odd phenomenon is easier to understand if we recognize that the impression of distance is a simple one-dimensional signal existing in the brain, derived from the perceived locations of various objects. Once derived, it exists along with the signals representing other attributes of the objects, such as their orientation, their size, their color, and so on. That's why, on close inspection, distance turns out to be a rather disembodied kind of experience. It's a function of what we see out there, but it isn't really out there, as it appears to be.

If you start looking carefully at the world out there, you will find more and more attributes, some simple and some rather complex, having the property we require. They can be present to greater or lesser degrees, or at least can vary in some simple way between one state and another state. Even when you're thinking about something very far removed from simple sensory impressions, such as the beauty of a sunset, you can begin to see it as an attribute which can vary from none at all (a murky smoggy sunset full of contrails) to some very large amount (a sunset which makes you run for your camera). In our usual states of inattentiveness, we normally speak and think of such "qualities" as either-or categories: that sunset was beautiful and the other one wasn't. If we attend more carefully, we can see that even such apparently either-or attributes really exist on a continuous scale of variation: more or less. Such an attribute could be represented by a single neural signal which varies in frequency as the attribute varies in amount.

Obviously, an attribute like beauty, even though its amount can be represented by a one-dimensional signal, can't be derived from signals standing for colors, color relationships, cloud shapes, shadows, and so on by any simple process. The beauty-ness which is experienced is a simple outcome of a very large set of complex processes about which we know essentially nothing. The people who try to model human perceptual functions still are having trouble figuring out how to make a machine recognize an "A" written in all the ways people can write it. If you asked them to explain how the machine could tell whether the "A" looks typographically nice, they would throw you out for mocking their feeble efforts. Theoreticians, fortunately, are allowed to speculate far beyond current understandings. Sometimes their speculations lead to research which wouldn't have been thought of otherwise, so they do have their uses.

Now we can begin to form a general concept of how perception might work. At many levels in the brain, attributes of the external world, initially represented as elementary sensory signals each representing only the local intensity of stimulation, are combined by neural computers to generate a new level of attributes. Each derived attribute represents only one degree of freedom of the lower-level collection of signals, and so can be embodied as a neural signal capable of varying only in its magnitude (frequency of firing). As we progress to higher and higher levels of perception, we find new attributes being created by new kinds of computing processes, the nature of each attribute being fixed by the way a given neural computer transforms and combines its inputs. Each new attribute is still one-dimensional, and can be represented by a signal's magnitude as being present to some degree, or being located in one place along its continuum of change. At every level, the signals remain simple, although as we move upward, their significance becomes more complex and abstract.

The same conception shows us where to look to find evidence about these levels of perception. We should look at the real outside world presenting itself to experience. If there are perceptual signals which depend on other perceptual signals, we ought to find that there are aspects of the external world which seem to depend on other aspects—not in the ways physics or chemistry would predict, but in ways which are arbitrary, given.

If there do seem to be broad classes of perceptions related in this way to other classes, we can take this as evidence that our brains, as well as the external facts of nature, are playing a part in creating these relationships. The structure of our own perceptual systems is laid out in plain view. All we have to do is look more carefully to see what we have been taking for granted. That is how the levels to be described next were found.

5.5 The Levels

Even though the picture we shall construct is speculative, it is based on evidence. As just noted, the evidence is to be found in your own experience of the world. This does not mean that we will glance at the world around us and then examine our inner reactions to it. That approach would set us back about 100 years, to the days of Introspectionism. As we look for evidence concerning human perceptions, what we see will not seem like perceptions. It will seem like aspects of the objective world around us. You will have to make a conscious interpretation, saying to yourself, "That appears to be there because it is represented in my brain." That is not how it will seem to you. The world will still appear to be solid, real, and outside.

We aren't trying to alter direct experience, substitute something else for it, or imagine that something else really is going on. We're trying to see how this ordinary world of experience can be explained in terms of a model which, in most cases, merely adds one simple comment to whatever you ordinarily would think about the world: "That is a perception." You also might begin to think such thoughts as "If I didn't have human senses and a human brain, this is not the world I would be seeing."

We shall start at the bottom of the perceptual hierarchy and work upward. After the first level, there will be some guidelines helping you to see the logic of the model. One of them is, of course, that the existence of a higher-level perception should depend on the existence of lower-level perceptions. But this is a control-system model, not just a perceptual model. We also require that if a higher-level perception is to be controlled, maintained in some specific state, then lower-level perceptions must be altered to bring the higher-level perception to that state (in a normal uncooperative environment).

The most important ground rule is that you should check out the proposed elements of this model directly. If one type of perception supposedly depends on another, you should not drift off into an intellectual dream and start manipulating verbal reasons why this should or should not be so. If the relationships are real, you will observe them whether or not they should exist according to any line of reasoning. The question is not whether we can explain rationally what is observed, it is whether independent observers can agree that there is a phenomenon needing explanation. In order to communicate what it is which should be noticed, we must use words, but words are not the phenomena to be noticed. The phenomena are the perceptions, the elements of the experienced world, to which we can attach words and about which we can think. The first step in this process is to observe in silence.

Where other kinds of evidence are available, we shall, of course, use them. Our aim here, however, is only to build a picture of the hierarchy. If you want to tackle the problem of refining and improving this picture, then there is a vast literature on the subject of perception, some of which would be useful in this application, which you can study. And there is an endless amount still unknown.

5.6 A Tentative Human Control Hierarchy

5.6.1 First-Order Perception: Intensity

We can begin, fortunately, with a clear link to neurological facts. All perception begins with stimulation of sensory nerve endings, whether they are sensitive to light, sound, taste, smell, effort, position, or any other variable, and whether the cause of stimulation is located inside or outside the body. Nerve-endings respond to stimulation by generating nerve-impulses at a rate depending on the amount or intensity of stimulation. Some of these responses exaggerate changes, but many sensors, perhaps even most, simply respond to a degree which depends on how much stimulation is present. The response isn't linear; it rises more and more slowly as the stimulation increases. But that nonlinearity makes no difference to the general picture.

The signals generated by sensory nerve-endings are essentially alike in nature. We do not experience them in their actual form (that is, the form we would see on an oscilloscope or EEG, trains of brief impulses), but in terms of their smoothly variable frequency. That is all we experience, because there is nothing else about the signals which can represent the kind of stimulation which is present. The signals represent an amount, but don't carry any added information indicating what *kind* of amount it is. The identity of such signals can be established only by higher levels of perceptual processes.

All experiences of any kind, involving any sense, therefore should have one aspect, one attribute, in common. We can call that attribute "intensity." This can be observed directly. Of course, you can't shut your brain down so it won't also notice many other aspects of experience at the same time, but you can in fact discern the attribute of intensity in anything you see, hear, taste, feel, and so on. You can compare the brightness of an illuminated surface, for example, with the loudness of a sound, and make a judgment as to which experience is of higher intensity. Comparing attributes requires higher-level functions, but that which is being compared is clearly intensity. You can observe changes in intensity, as when you press down lightly on a tabletop and then increase the pressure. The sensations from the skin will start at low intensity and then increase, and so will the sensations of effort.

It is interesting that this common attribute of experience exists at all. Very few sensory nerves send their signals all the way to the cortex of the brain, and those which do connect only to specific areas, which are *not* those with which conscious experience traditionally has been associated. Perhaps consciousness is not the same thing as the activities higher in the brain; if it were, we would have a hard time explaining how we can be conscious of intensity.

5.6.2 Second-Order Perception: Sensation

When you compare sight with sound or object with object in terms of intensity, you ignore most of what you can perceive. The simplest thing you ignore is the quality of the perceptions. A loudness is clearly not a brightness. But how is it not? If you try to find evidence in experience which distinguishes between loudness and brightness, eventually you must give up. They are just different, as if they were in two different places. The difference in quality eludes close inspection. Under conditions which the Gestalt psychologists of the 1920s and later learned to set up, people actually can have difficulty deciding whether an isolated sensation is auditory or visual. Normally we experience a world of sensations in which the whole array is present; it is as though sound is identified mainly by not being what all the other experiences are which aren't sound.

You aren't likely to have a problem with distinguishing the brown of a tree trunk from the white of the snow or the green of the grass around it. These second-order perceptions behave properly when they all are experienced together. You can see that there is more to each of them than their intensities. Yet suppose that an eclipse of the sun now began to take place. The scene you are looking at would get dimmer and dimmer, but all of the sensations of color, edge, roughness, shading, and the rest would retain the same identity—until finally the light went out altogether (a total eclipse). With zero intensity of the underlying sensory signals, there can be no sensations. Some sensations such as colors fade away at low intensities; then we see that there can be intensity without a particular sensation which depends on the intensity.

A sensation like "blue" does not arise directly from the retina. A single short wavelength of light seen as blue stimulates all three kinds of color receptors, red, blue, and green; they all emit signals at once. Any mixture of wavelengths creating the same proportions of intensity signals from the three kinds of receptors will lead to precisely the same sensation of "blue." So the sensation of blue does not correspond to any one thing in the physicist's model—in "physical reality." The physicist measures wavelength by using a prism or diffraction grating which spreads light out along a line according to wavelength. A photocell placed anywhere along the line will emit a signal showing how much light is there; its position tells the physicist what wavelength is being measured. The eye doesn't work like that. The color sensation is ambiguous with respect to physical reality.

This is true of all sensations. All sensations are derived by combining intensity signals coming from different sensory receptors. The intensity signals presumably are weighted as they enter second-order perceptual functions; some add and some subtract, by various amounts (at least that would make sense of the phenomena). The result is that there are ways in which the individual intensity signals can change together which will leave the second-order sensation unchanged. This is how invariants are created. If the intensities change in any other combination, of course, the amount of sensation will change, becoming larger or smaller. Every invariant also defines a variable. If there are different second-order perceptual functions receiving signals from a common set of intensity signals, weighting them differently, a change in the intensity signals might reduce the signal from one sensation-detector, while increasing the signal from another; blue is replaced by yellow, or blue remains blue while its saturation (ratio of color to whiteness) changes.

There is much experimental evidence concerning the relationship between second-order and first-order perception. In direct experience, the phenomena revealed by these experiments are not all self-evident; after all, when you see a blue surface, you're experiencing only the response of a second-order perceptual function, and you would have great difficulty distinguishing the three brands of intensity signals which give rise to this sensation (although some artists claim to be able to do it). You easily can detect the total intensity, but because intensity signals are all alike, there's nothing at that level of observation to show which is the blue one, the red one, or the green one. The intensity signals don't have any color.

5.6.3 Third-Order Perception: Configuration

In visual perception, sensations clump themselves irresistibly into objects. The third order of perception receives the signals which are sensations, each third-order input function receiving some subset (perhaps overlapping) of those signals, and generating a new signal we experience as an object-attribute. The computing processes at this level must be either very complex or very different from what people trying to emulate object-perception with machines have been attempting to do. Even though we're only at the third level of perception (out of 11), we are faced with computing processes doing things beyond our present comprehension.

We only can observe the phenomena and wonder how the brain creates them. The phenomena aren't hard to see. Any object, if you examine it closely enough, proves to be composed of sensations. You almost can define "sensation" that way: it's an element of an object which isn't simply a smaller object. If you look for attributes of any object fitting that description, you'll find yourself experiencing sensations which are not themselves objects.

Consider a very simple object, a round black spot on a white background. The sensation inside the spot is called "black"; outside the spot, it's called "white" (of course, neither sensation is a word). These sensations depend on each other and on surrounding sensations, and both depend on intensity, but the spot itself depends only on the difference in sensations outside and inside the spot. If you imagine gradually brightening the black area inside the spot until it becomes the same white as the surroundings, you will understand that if the two sensations inside and outside the circle are identical, there can be no spot.

The same phenomenon could be seen if the spot were green and the background were yellow. By gradually changing the spot color from green to yellow without changing the total intensity, we again could eliminate the spot. Or we could splatter black and white, or green and yellow, all over the piece of paper without creating a circular spot; it isn't necessary for the spot to exist in order for the sensations of color to exist. But it *is* necessary for at least two different sensations to exist if there is to be a spot, or any other shape. By asking what kinds of differences are needed to create the impression of a spot, we can enlarge our ideas of what a sensation is—for example, a spot could be seen if the surfaces differed only in texture. So texture may be perceived at second order. We work our way back and forth between levels, trying to adjust our understanding so that the levels make mutual sense.

A general term which seems to be appropriate for many kinds of sensory experience at this level is "configuration." This word suggests some familiar shape or arrangement which can be recognized as a unit. It can apply to any sense. A musical chord, for example, is composed of tones of different pitch. As the pitch changes, the perceived chord changes, for example from a major to a minor third, which sound quite different—at the configuration level. So pitch may refer to sensation, while chord refers to a configuration of pitches. It's clear that in order to have a major third, it's necessary to have three particular pitches present; if one of the pitches changes, the major third very rapidly disappears. If all of the pitches increase or decrease by the same ratio, however, we have the impression that one configuration, the major chord, remains the same chord —not changing to a minor chord or a seventh. On the other hand, it isn't necessary for a major third to be perceived in order for pitches to be perceived: which one depends on which is perfectly clear.

5.6.4 Fourth-Order Perception: Transition

There's a nice illustration of the next level in an effect which movie-makers began using, and then overusing, some years ago. The scene begins with a sepia* photograph of a street-scene. This scene is full of recognizable configurations from border to border; cars, people, a dog, buildings, trees. Then the sepia areas begin to take on color, and suddenly everything is in motion. The people are walking and gesturing, cars whiz on out of the picture while new ones appear, and the dog sniffs at a tree, the branches of which are gently moving in the breeze.

A new class of perception has been added: motion. But it's a little more than just spatial motion; it's change in general, which is the reason for saying transition instead of motion. When the colors began to appear, they were not just colors, but, for a time at least, changing colors. We could have distinguished a gradual change from a rapid change—either in position or in color. If a big hot-air balloon landed in the street, we would see not only its rate of descent and then the disappearance of that downward movement, but the slow change of shape and orientation as the balloon gradually deflated.

We model this level in the obvious way: we suppose that the fourth-order input functions receive signals standing for configuration attributes, and generate signals at a new level which represent the rate of change of the configuration signals. It's clear that lower-level signals—sensations and intensities—are also received this way, and contribute to the sense of transition or change. This muddies the structure of the model a little, but we have to accept what we see. If we remember that a given level may receive information from more than one level below, we can focus on finding the least step from one level to the next, and speak mainly of the relationship between adjacent levels.

It's obvious from the example above that configurations (and sensations and intensities) can exist in perception without any transition-perceptions existing. But the opposite is not true. There can be no perception of transition without perception of configurations or their elements. In order to create or maintain a given transition-perception, it's necessary to act in a way which changes configu-

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*All in brown.

rations and so on. But configurations can be changed without necessarily creating any particular transition-signal. If configurations change in one way, we might see "spinning." If they change in another way, we might see "motion" without spin. If they change in a "disorganized" way, we might sense change, but no familiar kind of change.

Rising, expanding, extending, straightening, flowing, rolling, bending, veering, spiraling, twisting—these words and many other "-ing" words usually denote transition as the word is intended here. Transitions occur in every sensory channel: a pitch can rise and fall slowly or rapidly; a major chord can retain its configuration while sliding up and down the scale, or a dissonance can resolve into a familiar chord. An odor can grow from faint to pungent, a taste can intensify or fade, an effort can relax gradually or grow rapidly again.

5.6.5 Fifth-Order Perception: Event

If someone tells you something which would be somewhat surprising if true, you might reply "Oh?" This sound begins with a medium-pitch "O" sound which remains steady for half a beat, then rises quickly to a somewhat higher pitch. If, on the other hand, you were quite alarmed by the statement, you might say "Oh?" in a way which begins at a higher pitch, then rises immediately and twice as far before the end. These two ways of saying "Oh" are two different auditory events.

An event is defined as a unitary package of transitions, configurations, sensations, and intensities, having a familiar pattern in time. An event "occurs." A golf swing is an event; a tennis serve is an event; a gun being fired is an event; handwriting the letter "l" is an event; uttering a syllable is an event; jumping is an event. While an event is in progress, there is a single perceptual impression of something continuing to happen. The duration may be long or short; what matters at this level is the sense of one occurrence which exists during the event and disappears when it finishes. Individual spoken or written words are probably perceived at this level by adults (although words have no meaning at this level—one needn't understand the language to distinguish a familiar word as an event). Speaking of anything happening "during" an event is probably wrong: the essence of event-ness is that it collapses an interval of time to a point.

Even when we speak of an event which takes hours to be completed, at this level we make a single package of it. This doesn't mean we can't perceive the same elements in terms of smaller events which span shorter periods of time. It just means that an event is experienced as a single thing: an opera performance is an event, as is the first act, as is the aria which finishes it, as is the trill at the end of a passage. At the event level, these smaller events are as unitary as the largest one. In the same way, at the configuration level, the arms, legs, back, rungs, and seat of a chair are configurations in their own right, as is the chair as a whole.

For an event to occur, it's obvious that transitions have to occur. But a transition can exist continuously without creating the sense of an event—watch the second-hand on an analogue clock, or a stream of rush-hour traffic. The elements of any event, as the term is intended here, are not just briefer events: they are transitions, configurations, and the rest.

This is the level of perception at which psychologists have been accustomed to seeing "stimulus" and "response." It's a natural mode of perception, but it has no physical significance. The physical world is not divided into events; physical variables are continuously related, and change continuously through time (at the macroscopic level of human experience). Most events clearly are *created* by the observer. If you observe any real event, you most likely will see that it actually doesn't have any beginning or ending. When people speak, they don't separate the words, but run one into the next without a pause; the listener creates the boundaries, giving the impression of one discrete word being heard at a time (fortunately for the speaker).

There are, of course, occurrences having natural boundaries, and these are the most convincing events. In physical reality, the boundaries are not as sharp as they appear to human senses, but we are speaking of perception, not the physicist's reality seen through magnifying devices on microsecond time-scales.

5.6.6 Sixth-Order Perception: Relationship

In mathematics, two variables are said to be related if, given the value of one of them, you can state a corresponding value for the other. When we speak of experienced relationships in the meaning intended here, we mean something similar: that two otherwise independent perceptions (events) are constrained, somehow, so their behavior is not totally independent. Two ice skaters, each moved completely by that person's muscles without any physical attachment to the other, still can create a pattern in which they circle around a common center. They act to preserve a recognizable constraint on their motions and positions, which we perceive as symmetry of motion and position.

When we see a dog chasing a cat, "chasing" is a relationship. We can see this relationship just as easily in a real cat and dog or in a toy where the cat and dog are mounted on posts driven around a circular track by a motor hidden in the middle. We could see the dog chasing the cat even if the figures remained on opposite sides of the circle; we usually don't choose to see cats chasing dogs, although we could see the motions that way. We can say that a cup "contains" coffee, or that the coffee "fills" the cup. Neither one is more correct; each simply expresses a different way of perceiving the same configurations. "Tick," we say, comes before "tock." But it's just as easy to hear that "tock" comes before "tick."

One relationship-perception is causation. We may see the cat as running *because* the dog is chasing it—that the dog's chasing is somehow affecting the cat's running. From another point of view (for example, the dog's owner's), we could see the cat as provoking the dog, by running away from it. In many cases, once you settle on a way of interpreting a relationship as causal, the "cause-ness" seems to embed itself in the physical world, so it's hard to get rid of, even when something happens to invalidate it. Magicians get a laugh from this effect. The magician gestures and a toy mouse floats up into the air. Then while he is taking a little bow, the toy mouse circles around behind him all by itself, breaking even the illusory causal illusion.

The relationship-level refers to constraints we describe with prepositions such as in, on, above, toward, beside, under, and so on, and comparatives such as larger, faster, farther, and sooner. In general, relationship involves lower-order perceptions which are in principle independent, but are constrained to behave or exist in related ways. When we say that a decoration is "on" a plate, we see the plate and the decoration as different objects, so it would not surprise us if the decoration could be scraped off (although we might be disappointed). When we think of an object as unitary, we don't see relationships in it: it isn't likely that we would see the left half of a cup as being "next to" the right half, unless at some time we saw the cup broken in two and glued back together. Of course, once any possible relationship is pointed out, you can see it.

The point isn't to discover relationships which people habitually recognize or assume, but simply to recognize that relationships form a type of perception, whatever the relationships are, and however we speak and think about them. They clearly are products of interpretation—clearly, because we have the option of seeing any given collection of lower-order perceptions as an example of an endless variety of relationships.

Any relationship is a variable attribute; as we place a cup "on" a saucer, the "on-ness" grows as the cup nears its final position, being correct when we release the handle. At the same time, the "distance" of the cup "from" the saucer decreases. If we discovered later that the cup had become glued to the saucer, we might consider it as too much on-ness, or start thinking of a single configuration: a cup-and-saucer, with *no* on-ness.

And of course we not only can perceive the constraints we call relationships: we can act to bring them about and maintain them in particular states.

5.6.7 Seventh-Order Perception: Category

We have been using this next level of perception all through this discussion, and indeed since the start of the book. At this level, the attribute of importance is class membership. "This," we say, pointing to some object, "is a that," where "that" is the name of some class or category. This person is a doctor. That dog is mine. Those flapping things in the sky are birds. This action is called "hopping." This event is called a "bounce." This relationship is called "on."

In each case, we don't mean that the particular object, motion, event, or relationship is the category. We mean that anything like it is an example of the category. If there's some operation, such as measurement, by which we could establish the particular "like-ness" meant, we can define the category as consisting of all perceptions which provide the same measure, or set of measures. But that is more like how a scientist would come to define categories. The natural way is far simpler: we form them arbitrarily.

When you say, "That dog is mine," you're referring to at least two categories. One is "dog," and the other is "mine." If you've ever seen a large dog show, you'll know that the category "dog" contains animals of just about any shape, size, or color which you could pick. You might conclude that there is something about all these different breeds which identifies them as belonging to a single category despite their obvious differences, and no doubt you could find it, or at least many common characteristics (such as panting or scratching at fleas). That is, more or less, the common idea about categories: a collection of things with a common characteristic.

But what common characteristic creates the category of things which are "mine"? We can speak of my thoughts, my name, my house, my friends, my team, and so on. What is the common characteristic of all these things? If you look at the things, there isn't any common characteristic. You might say that the common characteristic is a particular relationship: things related to me in the manner of possessions. But what is a possession? A possession is a category of things I can, for example, sell or give away. How does that fit with speaking of "my weight"? Trying to find some simple succinct verbal rule which always will identify things as belonging in the category "mine" quickly turns into an exercise with a dictionary or thesaurus. And as you go through this exercise, you'll find yourself flinging about the names of other categories, so you end up defining one category in terms of others, and getting the members of categories (lower-order perceptions) confused with the names of the categories, and the names confused with the categories themselves, as if you couldn't tell "hot" from hot.

The easiest way out of this tangle is to propose that we create categories simply by creating them. We look at the thousands of shapes in which we see living systems, and then simply draw boundaries around them to separate them into groups. We form and reform categories until they are useful—until we can predict at least something about all of the items within one group simply by seeing them as members of that group and not another. Things which are dogs, chase; things which are cats, hiss. Of course "chase" and "hiss" are the names of categories to which leopards and snakes also belong, and calling some sound-event or visual configuration a "name" is to invoke still another category.

When we try to designate a particular perception by naming categories—when we try to talk about it—we have great difficulty. If I (a generic "I") say, "that thing standing over there," I might mean the floor-lamp, the umbrella stand, or my uncle. If I add "the thing with two legs," I may have eliminated only the lamp. I also could say "the thing that's always falling over" without really clarifying the situation. Short of speaking my uncle's name, I would have to intersect many classes before there was only one lower-order perception left, the only one which was an example of all the named classes at once. Of course, I could point or otherwise demonstrate my meaning, but that requires only lower-order perceptions. Try telling someone (without pointing) which person in a class photograph (all strangers to the listener) is the one you mean, and listen to the categories you bring up, trying to find a set which isn't too large, so that only one person in the photograph belongs in them all. Communication rests largely on common perceptions of categories, arrived at through a long period of learning with many mistakes. How many different animals does a small child call "doggie"?

Categories are not words. The words we use to point at categories are configurations or events used as names. We understand that the word "dog" is to be treated *as if* it is in the same category as all of those animals. To refer to the category, we either can point to a dog (any dog) or use the word. We can use any perception as the label-member of a category, even one of the normal members picked at random: "one of these," pointing to your own dog. How tiresomely often do we hear sports announcers doing this? "He's not one of your Bubba Smiths or Joe Louises." It might be simpler to say he's not a "prominent athlete," but perhaps the announcer simply has grouped people together in his mind as belonging in the same category for no reason he could describe clearly, or simply through familiarity.

At the category level, we have perceptions which stand for either-or entities, the first we have encountered. While a given item might belong simultaneously to many categories, it is either in one category or not in it. This either is an Airedale or it's not, although it may continue to be mine. Some dogs are better Airedales than others; that's what makes for dog shows. Even though Airedale-ness is variable, from hardly any to a lot, and can be controlled by selecting among similar dogs or by touching up one dog a little, the kind or category itself doesn't change until we get close to the boundaries of the category.

If we see a picture of a dog which slowly transforms itself into a cat, we'll hang onto the "dog" category until the "cat" category has become so prominent in perception, we *have* to switch. If the cat-shape then transforms back into a dog, we'll cling to the "cat" signal until the "dog" signal is too large to ignore. This phenomenon is called "hysteresis" by perceptual researchers; it results in the same shape appearing to be in different categories, depending on what was seen previously. Those who model perceptual phenomena as computations need to account for phenomena like this.

One of the difficulties in grasping lower-level perceptions is that we can't help applying higher-level interpretations to them. Sensations, as we naturally speak of them, have identities—we name them, and thus put the underlying experiences into categories. To experience what is meant by a perception at any level, you must distinguish it from higher-level perceptions based on it. It's therefore a little difficult to avoid applying the wrong level of perception until you have at least sketched in some prospective definitions of all of them. We've just introduced a level which removes identifications in terms of categories from the discussion of lower levels.

We also have introduced the first level at which we can think of experiences as elements of language. Of course, we name things like sounds, formants, phonemes, morphemes, and words, which are experiences of low order, but they are not linguistic elements until we reach the level of categories—where we do that naming.

5.6.8 Eighth-Order Perception: Sequence

Only a few years ago, the fifth level, events, was called the sequence level by control theorists. Nobody was very happy with this definition, because events are really unitary perceptions. Nevertheless, it was obvious that an event always had a beginning, a middle, and an end—a sequence of configurations and transitions. The apparent misplacement of the sequence level didn't become clear until the category level had been around for a while. Then someone (actually, an advanced piano teacher and control theorist named Samuel Randlett) noticed that "beginning," "middle," and "end" are categories, and that an event whose elements are put in these categories isn't an event any more, but three distinct entities. These entities always occurred in a given order—never, for example, beginning-end-middle.

At the sequence level, we perceive in terms of the ordering of discrete elements. The sequence A,B is perceived as something different from the sequence B,A. The sequence "Now is the time" provides a strong sense of recognition; if it is followed by "for heads to fall," we recognize another familiar sequence, but it is not the expected continuation of the first one. We perceive two sequences, making a longer sequence. "John hit Mary" is perceived differently from "Mary hit John," simply because the word order is different. In English, the relationship implied by the word "hit" carries a direction from the first element to the third. In other languages, the implication goes the other way; the object is normally given first, with some added help from word endings.

There is more to sequence-perception than its linguistic uses. It's involved in any skill which is at all complex. In most skills, the sequence in which particular acts are carried out must be controlled; when you shoot an arrow, for example, you should aim before, not after, you release the arrow. If you can't tell the difference, you'll hit the target only about half the time. When you tie shoelaces, the bow knot comes after the overhand knot. When you sing a melody, the different notes must occur in one and only one sequence; if you produce the same notes in some other sequence, you'll detect an error in the melody, or perhaps recognize a different melody. If you hear an unfamiliar melody, you'll perceive bits and pieces of familiar ones, as various sequence-recognizers respond here and there, but you won't have any perception of a sequence.

The term sequence is meant here to apply to particular familiar short single or repetitive series of elements (elements drawn from any lower-order perceptions). A particular sequence has elements which always occur in the same order, a fixed routine. As soon as the sequence begins, perception reports that it is in existence; this impression continues as long as the sequence unfolds in its standard form. "When in the course of human affairs"—there is already a sense of a familiar sequence, and it will continue as long as the words continue to be taken in the order of occurrence in the Declaration of Independence.

5.6.9 Ninth-Order Perception: Program

Categories are at the level where we begin to use specific perceptions of lower order as symbols. Sequences are specific orderings of these symbols. At the next level, symbols and sequences of symbols are perceived in terms of a network of relationships similar to those found in computer programs.

What is it about the way these elements occur which is "similar to" a computer program? It is not the fixed sequence in which they occur, but the fact that there are branching pathways, different pathways being followed depending on what else is going on at the time. An act such as writing a check is purely a sequence, but only if you have the pen in your hand with the checkbook already open before you, and know what number you intend to write. Normally, when you decide to write a check, you don't know for sure where the checkbook is, and you may have no idea what pen you will wind up using. If the pen is in your coat pocket hanging in the closet, you will have to get up and go to the closet, an act which otherwise doesn't have much to do with writing a check. You may have to go out and buy a pen before you start writing. So the acts you call writing a check really depend on many aspects of the present world which are not likely to be the same twice in a row. Some of these differences can be handled at lower orders. If your hand is to the left of the pen, you move your hand to the right, and if your hand is to the right of the pen, you move it left. That can be reduced to simple relationship control which you don't have to symbolize, because the underlying spatial relationships involved never change. But when you decide to have pancakes for breakfast, the moves you make, the particular relationships you bring about by acting, depend on where things are and what ingredients are available, and the way they depend is of a different nature.

The essence of a program is a test followed by a choice: if this is true, do one thing; if it isn't true, do something else. There can be multi-way branches, too —not all logic is binary. When you think of a program in a general way, you can discern this "if-then" structure without having to know which path will be taken on any specific future occasion. You can perceive the logic of the network of choices, as if you could imagine all of the paths simultaneously and understand what would make the difference in path, what would lead you to take one route through the pattern of choices, rather than another. A chess player recognizes a program when a "fork" occurs: if I move the king, I lose the queen, and if I move the queen, I'm in checkmate after one more move. This is the kind of thing meant by "program perception." It isn't the perception of a particular sequence of occurrences: it's perception of all the possibilities, as far as we can grasp them, at once. Where we perceive descriptions at the category and sequence levels, at the program level we perceive implications.

At the program level of perception, we carry out the operations of manipulating symbols we call "understanding." At the program level, rules determine how one set of symbols and sequences of symbols describing lower-level perceptions is converted into new symbols and sequences of symbols which are interpretations or implications of the category and sequence perceptions. As the lower-level world changes, so do the implications we perceive, and so does the understanding of what is happening change. We compare that understanding with descriptions of what we want to be happening, and if there is a difference, we reason out what to do about it. When we choose actions based on this reasoning, we alter the world experienced at lower levels, changing the categories and sequences being perceived, and thus changing the implications which we perceive. We control implications by altering premises, and we alter premises not only in imagination, but by physically acting to alter the lower-order perceived world.

For example, if the technicians at the Three Mile Island nuclear power plant had perceived the implications of certain meter readings, they would have perceived that something was drastically wrong. They then would have used the control mechanisms available to alter the state of the plant in the logical way, changing the meter readings until they implied a status closer to what was intended. That might not have saved the plant (one of the meters was wired to show the status of a command switch, not that of the water valve which failed, so the reasoning was partly based on a false premise: a perception which was a lie), but it does illustrate how a *program* can control a desired state of affairs by using whichever action-sequences apply in the current situation.

While programs can be extremely complex and many-layered, once they are written, they have a fixed structure. This does not mean that they produce fixed sequences, but only that the structure of choice-points, the range of possible pathways from one choice-point to another, is completely determined. Even when the program is so complex that we can't grasp all its possibilities (or even a small fraction of them), all of the possibilities are inherent in the way the program is organized. This predetermination, however, doesn't mean that a program must always do the same thing after it is set up. A program is not a sequence. If the perceptions constituting the inputs to the program change, different branches will be taken at the next choice-point, and because lower-order perceptions continue to figure into the process at every stage, each following step will involve choices that are just as unpredictable as the perceived world.

Furthermore, human programs are not like the programs which run in "Von Neumann" machines, machines with only one computing processor. Human programs run in parallel; many programs are in progress at the same time. You can be driving to work, watching out for the car ahead whose behavior suggests that the driver is drunk or otherwise incompetent, while thinking about how you're going to ask for a raise, and wishing you hadn't had that extra cup of coffee at breakfast. Your brain can be running programs of which you know nothing until suddenly the answer to a nagging question pops into awareness.

Those who are interested in Artificial Intelligence and other kinds of computer models of the brain are attempting to imitate this ninth level of human operation. It's obviously a very powerful capacity of the mind, capable of constructive use and terrible misuse. It is clearly not the only level, and as we shall now suggest, not the highest level, either.

5.6.10 Tenth-Order Perception: Principle

A great many aspects of human thought can be imitated as specific computer programs. But there is one aspect which can't be treated that way, or at least hasn't been treated successfully that way so far. That is the process of creating, altering, and judging the worth of programs—generalizing about them.

There seems to be a kind of "law of awareness," to the effect that when you are consciously occupied with a process at a given level of perception, you aren't conscious of any higher levels, or of that level itself. It's as though you're occupying a particular level and using it as a viewpoint from which to see the lower levels of perception. When you look at relationships, you're not conscious of categorizing them, making sequences of thoughts about them, or reasoning logically about them. It just seems that the relationships are logically related. The only way to examine the aspects of the world which are operating in your current base of consciousness is to move your base. We've been doing this again and again as we've gone from one level to the next in this chapter.

The program level is where we think. Normally, we aren't aware of thoughts as thoughts; we think them about something else. Then we are the thoughts, and aren't examining them. We see through them as we see through glasses which tint the whole world: seeing from the ninth level makes the world look logical.

To see what the next level is supposed to mean, we have to step back and look at the program level as a collection of processes we can experience without identifying with it. One way to do this is to construct a simple thought-paradox: for instance, think the thought, "This is not a thought." If you're still identified with the ninth level, this thought will create all sorts of problems; it will evoke a stream of other thoughts commenting on it, like independent demons irritated at the presence of this ugly stranger in their midst. "What do you mean, this is not a thought? If it's a thought, it's a thought. It's just a false thought." And so on. The point is not whether the thought is true or false, but that you can generate it, think it, and observe it as a thought. Once you can do that, you can do the same with all other thoughts about that thought—they're just thoughts going by, too. In order to do this with all thoughts, you must be observing from a point of view which isn't involved in thinking.

That's a pretty esoteric and introspective suggestion, and leads in directions we don't necessarily want to go right now. It's only meant to jog you temporarily out of a totally verbal and logical frame of mind, so you can begin to see that the world has aspects in it which are of a higher level than programs. We can call this higher level the principle level.

We can express principles as words, and we can think of program-like examples of them, but we can't perceive them at those levels. A mathematician named Richards once said that he couldn't show anyone a proof of a theorem; all he could do is describe the proof using mathematical symbol manipulation. It's perfectly possible for a person to follow a train of logical symbol manipulation, and (as most of us know) still not see it as a proof—that is, not grasp the general principle which is illustrated by the logical process. That may be what Richards meant.

Most principles are, by their nature, general and imprecise. Consider, for example, the moral principle that one should be honest in dealing with other people. Most of us can look at the way people act and interact, and form a perception of how honest they are. But how many of us could define what we mean by that? We could illustrate what we mean by giving examples, such as the example of Abe Lincoln walking miles to repay a penny to someone (whether that ever happened or not, and whether or not we consider that to be too much honesty). But where is a principle to be found in a person's taking thousands of steps and then handing a small object to another person? The illustration doesn't mean a thing unless you already are capable of perceiving it as an example of something more general: a principle.

To perceive honesty doesn't mean just perceiving this program or that program in action. It means drawing a generalization from all of the programs which can be discerned. We can refer to this generalization with a word like honesty, but honesty isn't a word: it's a sense of pattern, like a rule which isn't stated in if-then terms. Programmers are always devising new principles and using them to guide the way they organize programs, but so far nobody has been able to write a program which can do this kind of thing. At this level, our brains work in a way which we haven't been able to capture in any set of prescribed procedures. Perhaps that's inevitable, because prescribed procedures exist at the ninth—program, not the tenth, level.

One of the goals of science is to represent nature in terms of general principles applying to a large range of specific circumstances. If scientists didn't have a tenth level of organization, they wouldn't be able to do this.

5.6.11 Eleventh-Order Perception: System Concept

Any principle applies to a range of logical processes, which in turn apply to a range of sequential procedures, categories of things and actions, relationships, and so on down the chain. A principle set up as a reference signal gives us a standard against which we judge the principle we perceive actually to exist in the world of experience: we may prefer honesty, but we also can see that the strategies a given person carries out impress us as examples of a very small amount of honesty. So we can detect principle-errors, which suggest ways of altering our own programs to correct them.

Now we are asking what can be seen in a collection of principles, each principle standing at the top of a downwardly-expanding pyramid of programs, sequences, categories, relationships, events, transitions, configurations, sensations, and intensities. As at any lower level, there are perceptions which hang together in a recognizable way, and others which seem to hang together in a totally different way. Principles such as conservation of energy, conservation of mass, experimental test of propositions, and representation through mathematical forms hang together in a way suggesting a particular science: physics. Other principles such as making a profit and balancing the books belong to a different group, having to do with finance or business. And principles such as honesty, tolerance, fairness, cooperation, and generosity hang together to give a picture of a certain way of being human. The name we use here for the type of perception drawn from these constellations of principles is system concept.

When you think of your family, another system concept, you don't think just of specific people like Joe, Elisa, Jane, and Pete, or just in terms of relationships like Mother, Father, Sister, and Brother, or just in terms of people's habits and routines or characteristic ways of reasoning, or just in terms of the morals the children were raised to believe in. You think of all of these levels at once, and the result is a sense of one unique entity, one system, my family, good or bad. Even when you interact with one person, the more you learn about that person's organization from the principle level down, the clearer is your impression of a unique personality, a being put together as no other person is.

System concepts can be goals, and they can be perceptions. We can set goals for system concepts, compare the sense of system we actually obtain with the one we would prefer, and learn how to alter principles until they make the experienced system concept match the reference system concept. We can think of being a nice person, perceive that we are not so nice, and try to change the moral rules we follow (and try to follow them more consistently) as a way of making the actual self-image match the desired one. Why we should bother doing this is entirely beside the point—no doubt everyone will have a theory about that. The point is that we do this sort of thing all the time, and any complete model of human nature has to include the system concept level, even if we understand very little about it.

5.7 Higher Levels

Have we reached the top? Who knows? Even if we have, there is no reason to think that this level will *always* be the top level of human organization; it's very unlikely that it existed in the human brain when the hominid called Lucy walked the earth two or three million years ago. And even if this *is* currently the top level, there's no reason to think that it works very well, or is organized as well as it will be in the future. There must be some level of organization where evolution is still at work, where we still are changing as failures of organization put us at risk. One only has to look at the state of the world today to know that human beings are not very well set up at levels like principles and system concepts. We often seem to pick our system concepts out of thin air and defend them to the death, even though it's obvious that in some areas certain system concepts are thought to be wrong by most of the people on earth (except the True Believers, each of the hundreds of different groups).

For most of us, our system concepts just happen; they operate above the level where we normally experience the world, and we aren't aware of how they got there. It's a rare person who tries to work out system concepts so they are mutually consistent, or who is even conscious of them as they direct the way the person reasons and otherwise lives. Principles seem to most people as givens which one just knows about: it's wrong to murder people and steal, mainly because those are bad things to do. How many people actually try to figure out what is good about the Ten Commandments or the Noble Eightfold Path?

The journey which we began eleven levels down has left us with many unanswered questions, and, at the top, leaves many loose ends which we simply have to leave dangling. Our own complexity is still beyond our comprehension.

5.8 Why All These Levels?

One of the problems with psychology and its allied sciences is that psychological theory has always been far simpler in its structure than is any actual organism. Not only that, but psychological theorists often simply have ignored the fact that they are examples of one of the organisms, the main one, whose nature they are exploring. In the course of devising experiments, carrying them out, and explaining the results, psychologists make use of an enormous number of human capacities entirely left out of their picture of "the subject."

In our travels up the levels in this model, we have encountered most of the types of perception and action in which human beings engage, including the important perceptions and actions involved in scientific pursuits. No doubt, important aspects of life have been overlooked, and it's perfectly possible that levels have been interchanged, or that some of them are unnecessary. As this is only a first approximation to a real model of human organization, we shouldn't think that it needs to be memorized, or that we must slavishly try to fit every example of behavior into one of its slots.

What matters here is the beginning of thinking about human organization in a way which begins to cover all the things people do and experience. What matters is that we understand just what it is we have to account for with a model of human nature. And what matters most is that we stop exempting some of the things which we ourselves do as we try to understand other people, stop giving ourselves some special place to stand or special abilities denied to others, stop taking for granted the very abilities which make a human being or an animal interesting as a whole organism.

The eleven levels of organization presented here are intended to remind you of everything which goes on, so you will realize that organisms do more than jump when you jab them. Even a simple organism is a complex structure functioning at many interrelated levels. If you don't have a concept of organisms as systems, you will never get anywhere with understanding them. What we have been through here is just one way of building up that kind of understanding. It's a starting place.

Notes

1. Another possibility might be that the highest-level system is in a process of slowly organizing (reorganizing) throughout life, and hence that it occasionally displays random actions. In everyday terms, this might look like: "I can't imagine why I did that; I'm just not myself today."

Foreword to Part 3

We proceed next to review the details of central nervous system anatomy and physiology, noting how the known facts conform with the basic control-theory model presented in the preceding chapters. Chapter 6 corresponds to the physiological psychology chapter in traditional texts. It is not intended to be exhaustive. Most of the control mechanisms of organismic functioning remain to be worked out; this work is going forward in many of the fields of biology and biological psychology, and increasingly is being presented in control-theory terms. The introduction to control systems given in the previous chapters will enable you to understand these new areas of research in a more integrated way. If you want to pursue the subject more deeply, consult neuropsychology and physiological psychology texts, and look for reports of the latest findings in journals such as *Science*, *Brain Research*, *Neuroscience*, and *Journal of Neurology*.

In the remaining three chapters of Part 3, we shall expand our speculations about the development of control systems in the growing person, and then discuss how these views apply to the traditional fields of developmental psychology, learning, motivation, and perception. Thus, Chapter 7 corresponds to an overlapping of physiological and developmental psychology in the traditional approach, Chapter 8 corresponds to the traditional chapter on the basics of learning theory, and Chapter 9 examines the subjects of motivation and perception as aspects of control, rather than as autonomous functions within the organism.

Part 3

The Organism as Environment Control System

Chapter 6

Control Structures of the Organism: Brain, Nerves, Genes

6.1 Basic Assumptions

The model of the organism which we present here—as a hierarchically organized environment control system—contains several assumptions which need to be made explicit.

(1) It is the organism, not its nervous system, which should be perceived as an environment control system. The nervous system comprises a major component of that function, but as part of the organism as a whole. It, along with the glandular systems, functions first of all to regulate the internal environment of the body —the tissue-fluid medium in which the cells of the body live. This medium must be kept at the proper temperature and chemical composition essential for the life of the cells.

All of the activities of the body (including behavior) ultimately serve this purpose—preserving the life of the organism by maintaining the internal conditions needed for the life of the cells. The body can control its internal environment, in the long run, only through its ability to control its external environment. This is accomplished mainly with action by its muscles—by moving the body or other objects around—although many organisms also exert control over their environments by means of chemical control systems.

Some glandular secretions, such as pheromones, act directly upon the environment, creating "disturbances" in the variables which other organisms control. Certain genetically structured (instinctual) systems apparently are set at "0" until a given pattern of sense receptor signals (chemical, visual, or auditory) is received; then the system turns "on"—to perform genetically programmed interactions between members of a species. Such signal patterns have been called "releasers" by the ethologists who have described these phenomena. When glandular outputs, rather than actions, supply the signal patterns functioning as releasers, chemical reactions play a part in controlling the external environment; however, the major aspect of chemical control is found in the internal environment.

Such biochemical regulation seems involved especially in aspects of sexual behavior. In some species, pheromones act like the scents of flowers, being detected by special sense receptors possessed by members of the opposite sex. These sense receptors initiate feedback signals in genetically fixed control systems regulating programs for reproductive behavior.

Genetic factors apparently are mediated through the regulatory function of genes in the control of protein metabolism—during embryological development, guiding the formation of the new members of the species, and continuing control over many ongoing processes, setting their reference-signal values. Recent investigations have shown chemical feedback-control systems at work in gene control of developmental and functional processes, although the exact mechanisms remain to be clarified in most cases.

(2) The overall purpose for which an organism controls its environment is to maintain and optimize its existence. Other basic assumptions, such as Maslow's (1970) and Rogers' (1951) postulates of a "drive toward self actualization," may amount to the same thing when translated into biological terms (see Reiner, 1968).

Thus, when the air outside your skin becomes too hot, the body's overall temperature control system begins regulating its various components to release heat. For example, lower-order systems controlling the openness of pores and amount of blood flow in given areas can release heat through evaporation by sweating and radiation. They perform this function by controlling contraction of the muscles surrounding pores and arterioles to whatever extent needed for the "supervising" level (of the temperature control system) to perceive its feedback signals moving toward the genetically determined "set point" for body temperature. The same system works in the opposite direction as a first line of defense when the environment outside the body is too cold. Preservation of optimal temperature-conditions for the survival of the body's cells is control of the simplest type —control of the immediate physical environment of small regions of body cells by regulation of a one-dimensional variable: degree of tension in the muscles surrounding the pores and blood vessels.

As stated in Chapter 5, control systems at all levels within the hierarchy work to control their perceptual signals. When you are acting to realize an image (or system-concept) of yourself as a person with income-producing skills, for example, a pyramid of complex control systems is involved in making that choice and carrying it out. The pyramid controls action to achieve and maintain a specific perception of your "self,"just as the system described above works to maintain a specified level of body temperature. But, in the case of the "self system," the result affects the organism-as-a-whole on a broader scale of time and space, by means of more complex controlled variables. It would operate in the same way in enacting a self-concept as a hobo, for example, but it would produce the opposite end result.

(3) We also assume that "mind" is a name for an aspect of a human organism's environment-control activities, and that it is derived from signals in the organism's control systems. We take no position on the metaphysical and theological questions of whether there may be forms of mind which are independent of living bodies; we only assume that "mind," "consciousness," and related psychological concepts refer to aspects of signal processing in the nervous system. Mind and body are aspects of the organism, not independent entities.

(4) Finally, we assume that as current studies in neurobiology, neuropsychology, physiological psychology, psychobiology, and general psychology begin using the control-theory model, they will converge on a unified conception of the organism.

6.2 Nerve-Muscle and Nerve-Gland Control Systems

This chapter corresponds with the chapters on nerve physiology and brain anatomy usually found near the beginning of most traditional introductory psychology texts. However, our purpose for this chapter is somewhat different from the intent for the "physiological" chapter of a traditional text, where it serves mainly to pay lip service to the belief that some day the biological underpinnings of behavior will be unraveled. Our purpose here is to begin examining the anatomy and physiology of the brain and nervous system in terms of the feedback-control model with which you became acquainted in Chapters 4 and 5. This task often will be difficult, not only because a great deal remains to be discovered, but also because even the most recently acquired information about control-system processes in physiology and behavior (see, for example, Granit, 1977) is usually reported in "stimulus-response" terms. This makes it difficult to get an overall view of the body as an environment control system, rather than a reflex-machine.

The questions we would most like to have answered—about the nature of the control loops in many nerve-muscle and nerve-nerve networks—are mainly unanswered. Nevertheless, we can make a significant beginning in examining the control-system features of neural functioning.

Take another look at the sketch of an elementary control loop in Figure 4.5, slightly modified below as Figure 6.1, and compare it to the sketch of the basic nerve circuit involved in regulating the tension of a single muscle fiber, shown in Figure 6.2. See if you can identify the elements of the conceptual scheme in the actual anatomical parts in Figure 6.2.

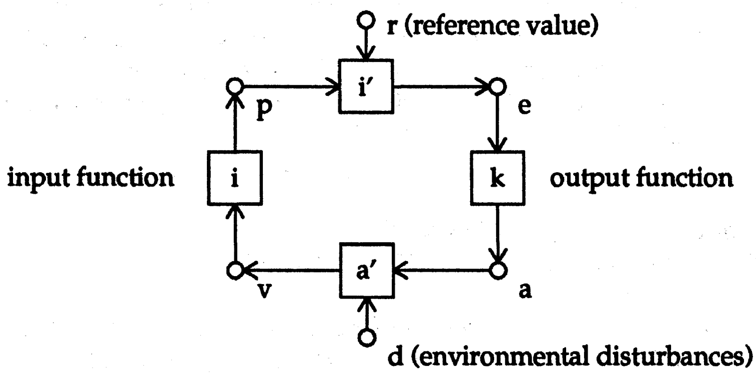


Figure 6.1 Control-system block diagram, modified from Figure 4.5

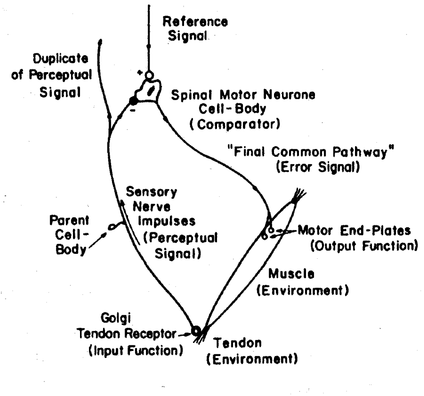


Figure 6.2 Idealized motor-fiber control system [reprinted with permission from: William T. Powers, *Behavior: The Control of Perception* (New York; Aldine de Gruyter) Copyright © 1973 William T. Powers]

Compare the neuroanatomy and the control-system labeling in Figure 6.2 with the control model in Figure 6.1. What condition is controlled by this system? Could it be called "environment," in any sense? (Think of the degree of stretch in the tendon holding the muscle to the bone as the environmental condition under control, because that is what is sensed by the sensory receptor, and that is what is "produced" by the action of the muscle.) Next, consider the question, "How many levels of control are involved in regulating muscle tension in this scheme?"

Did you come up with the answer "one"? If you note that the system controls the amount of tension, or contraction, of the muscle, then it becomes clear that the variable "tension" has a single dimension: there can be more tension or less tension. That's all. Thus, it conforms to the definition of a first-order system; it controls a single-dimensional variable, which can be expressed in terms of its magnitude or level of intensity.

Ultimately, all behavior involves movement, which in turn involves complex combinations of muscle tensions, acting over time and space. The reference signals coming into such first-order control systems constantly are being reset as part of more complex control loops (second-, third-, and higher-order systems) involved in the sensations, configurations, transitions, and events which we perceive as postures, movements, and actions. An organism with only two orders of control presumably would not be able to move. It only could vary its muscle tone, and sense variations in effort while doing so.

It requires a combination of tensions in a group of muscles to maintain the position of structural members of the skeleton (*configuration*). And it requires a sequence of alterations of positions to produce movement. The anatomy of the brain consists of higher-order circuits which control the organism's perceptions of variables such as those just mentioned, and even higher-order variables, as described in Chapter 5.

6.3 Anatomy, Physiology, and Psychology: Their Relationships in the Control-Theory Model

Most readers have seen a picture of the brain, with its various lobes, and a midsection with its several structures, and have a general idea that different parts of the brain do different things. In fact, however, while we have general ideas and rough anatomical maps of where different functions seem to be concentrated, we are largely in the dark about how they work together. Before examining the complex picture of control in the human organism, we shall review how one type of simple organism exercises control over its environment with various simple feedback controls. This is the bacterium *Escherichia coli*, as described by Daniel Koshland (1980). This bacterium performs all of the basic functions which we do: it eats, it moves, it reproduces. Yet it has neither nerves nor muscles. In its single cell, there are biochemical energy transactions similar to those performed in our nerves, our muscles, and our digestive and circulatory systems.

Koshland (1980) explains the mechanics of these functions. Molecules of the several nutrients on which this bacterium lives can lock onto certain sectors of its surface membrane. These surface areas are constructed in such a way that only the right nutrients will "fit." When the proper nutrients attach to the bacterium's surface, they are absorbed through the membrane. Other biochemicals within the cell detect the rate of nutrient absorption. These, in turn, interlock with still other chemicals which change their composition according to whether the current rate of nutrient absorption is faster or slower than the just-previous rate—a primitive form of "memory." Depending upon whether the bacterium is moving toward an increasing or decreasing concentration of food, it either keeps going in a straight line or, when the concentration begins to decrease, the drop in energy shuts down the "motors" of flagella, by which it moves, stopping its movement and causing it to tumble about. In a moment, it starts moving again in a random direction, since it has no mechanism for steering. It starts and stops, tumbling repeatedly (if needed), until a new direction results once more in perceiving an increasing concentration of food.

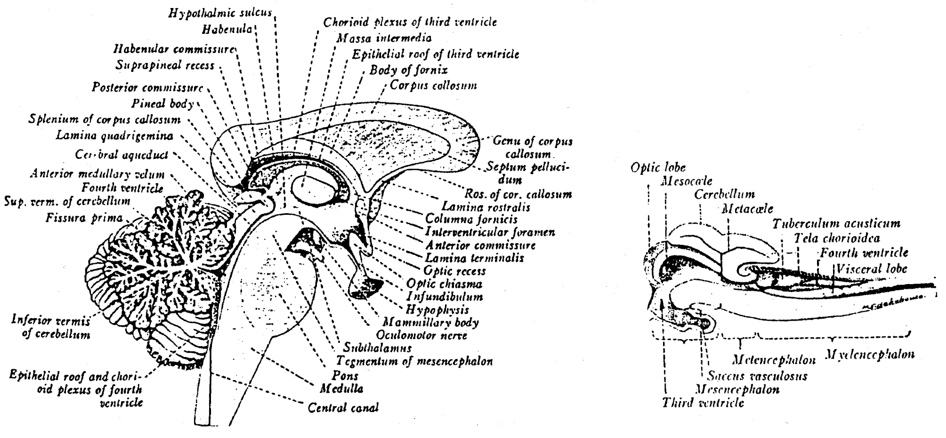
The most interesting thing about this bacterium, for our purposes, is that the complex protein molecules involved in these functions are similar to those found in higher organisms, including ourselves. Because of accumulating observations of that sort, we feel justified in tentatively filling in the blanks of knowledge of our own mechanisms by speculating with analogies to known mechanisms in simpler organisms. Such speculation gets support from the known facts of comparative embryology, where we find that higher life forms tend to progress through several stages. These stages of fetal development are somewhat similar to the forms found in more primitive species. This parallel is expressed in the statement "ontogeny recapitulates phylogeny." The human embryo—during early development—looks first like a cluster of single-celled organisms, then like a fish embryo, then like an amphibian embryo, then like a reptile embryo, and finally it takes mammalian form. When dissected, human anatomy still shows many of these "primitive" structures, although in modified form.

It seems that life evolved more complex forms by gradually adding small refinements and "improvements" to existing species until they turned into new species. It reminds us of the way that a computer programmer will add embellishments to a program until it finally becomes so complicated that the original, simple form is practically unrecognizable, hidden deep within the final version. This way of adding refinements is usually more economical than starting over from the beginning every time. But it has some drawbacks, too. The "primitive" portions may be duplicated several times, with slightly different versions, creating possibilities for inconsistent actions, under certain circumstances, in the organism.

The oldest part of the human brain, the brain stem, looks vaguely like the brains of much simpler creatures (see Figure 6.3). It is essentially a thickened trunk at the end of the spinal cord. It functions much like a simple creature, too, being concerned mainly with the regulation of the fluid environment in which the cells of the body live—working to keep that fluid medium chemically similar (interestingly enough!) to the composition of the ancient sea in which, we presume, the first living cells came into existence.

Figure 6.3a shows a sectioned view of the human brainstem; Figure 6.3b shows the brainstem of a dogfish, without the attached higher brain parts. Note the similarity in general outlines. The dogfish's brainstem forms the major part of its control systems, and its life activities are concerned mainly with immediate life-support and reproductive functions, as are the analogous systems in the human brainstem.

This gives us a dramatic view of the nature of "higher evolution." The earliest single-celled creatures weren't very adaptable, as compared with higher animals. If the sea were to boil in a given area (for example, because of the outflow of a volcano), those cells floating in the immediate vicinity would die. They could not flee for their lives as higher forms can do under similar circumstances. We humans can do even more than just flee an inhospitable environment. We can build boats, dams, and roads, study the nature of earthquakes and volcanoes, and exert more control over the forces of nature, rather than be wholly at their mercy.



Human

Dogfish

Figure 6.3 Human and dogfish brainstem sections [reprinted with permission from S. W. Ranson and S. L. Clark, *The Anatomy of the Nervous System*, 8th edition (Philadelphia; W. B. Saunders) Copyright © 1947 W. B. Saunders]

Thus, the long, unbroken chain of developments—from the most primitive living cells to the highest life forms—has increased the ability of higher forms to survive more varied and complex environmental challenges. The primitive needs still are found in our own cells' requirement for a stable and narrowly defined "seawater environment." This is provided by the organization of higher-level organ functions, and by the actions we take in our external environment to obtain the basic conditions and nutrients needed for our body chemistry, which ultimately serve to maintain the body's internal environment so stably that the life of the cells goes on unaffected within the tremendous variety of external environments in which humans are able to live.

This chain of developments has parallels in the increasing complexity of the variables controlled by higher life forms: the lower levels of complexity still are preserved in the fixed "instinctual" (evolutionarily "middle-aged") parts of our brains, and the more complex variables are controlled by control systems which can be developed in the newest parts of our brains through learning.

Whereas single-celled creatures incorporate all of these functions within one cell, we find in more complex organisms that increased control of the environment is gained at the cost of specialization on the part of single cells. Let us look for control loops of the simplest type in the body, and see how many cells are involved. Reexamine Figure 6.2, which shows the basic control system for tension in a single muscle fiber, with its nerves labeled in control-function terms. We notice that control over the amount of "pull" exerted by this fiber requires: (1) a nerve cell which conducts the feedback signal from (2) the sensor which measures stretch in the tendon; (3) a nerve cell which functions as a comparator; (4) a nerve which supplies the reference signal; and 5) the motor end plate connecting the comparator with the muscle—five components to control the intensity of contraction.

This arrangement is already considerably more complex than that found in some lower animals, where certain muscles appear to function merely in an on or off manner. The system sketched here can be involved in finely graded changes in degree of tension. When many such fibers are combined in a muscle, the result is the precise control which allows us to pick up a hair or a sack of flour, open a door in a strong wind, etc. Higher-order variables are needed (and hence must be capable of being controlled) for such finer shades of action, and this requires increasingly complex systems, which in turn call for greatly extended nerve networks.

Recent research has shown that more complex control systems employ both nerve and chemical messengers to conduct the signals which are needed in them. Figure 6.4 is a sketch of a nerve cell and its message-carrying fiber, called the axon.

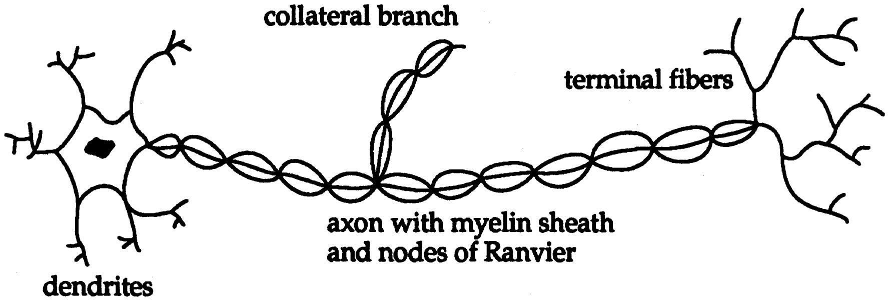


Figure 6.4 An idealized neuron

The signal which moves down the axon is a moving region of electrical discharge in which calcium ions flow out through temporary openings in the cell membrane. It moves down the fiber in much the same way a flame travels down the fuse of a firecracker, except that the nerve cell reconstitutes itself again behind the discharging "spark." When this wave of electrical discharge arrives at the end of the nerve fiber, there is an outflow of chemicals called "neurotransmitters," which cross the tiny gap to the next nerve and (if concentrated enough) cause that nerve to fire in similar fashion.

Thus, nerve signals can travel over chains of neurons, forming circuits of varying degrees of complexity in the brain. Furthermore, recent developments in neurobiology and biochemistry indicate that there are many different neurotransmitters, each type affecting only certain neurons and not others. Future research may find that this is how "crosstalk," or interference between closely lying circuits, is prevented. (For a more detailed discussion of the neurochemistry of behavior, see Panksepp, 1986, or other recent books on psychobiology).

How is the control of many first-order muscle tension systems coordinated in an action? Second-order systems, whose output signals influence groups of first-order systems, would work to coordinate them so as to produce the appropriate amount of effort required to satisfy specifications given by third-order systems above them. What condition would the third-order systems control? Think of the combination of efforts required simply to stand motionless in one place, instead of being toppled over by the pull of gravity. Although the body seems motionless, there is a continual play of pulls and pushes within the body to maintain the particular configuration of the body parts which is observed at any given moment. Figure 6.5 presents Powers' (1973) suggestion of three levels in the wiring of the human cerebellum involved in maintaining bodily position.

There need to be many different configuration-control systems in the human organism. The maintenance of a position configuration, by muscles holding the body in one position, is paralleled in many other actions. To make a single phoneme—the sound elements of which speech is comprised—requires a con-

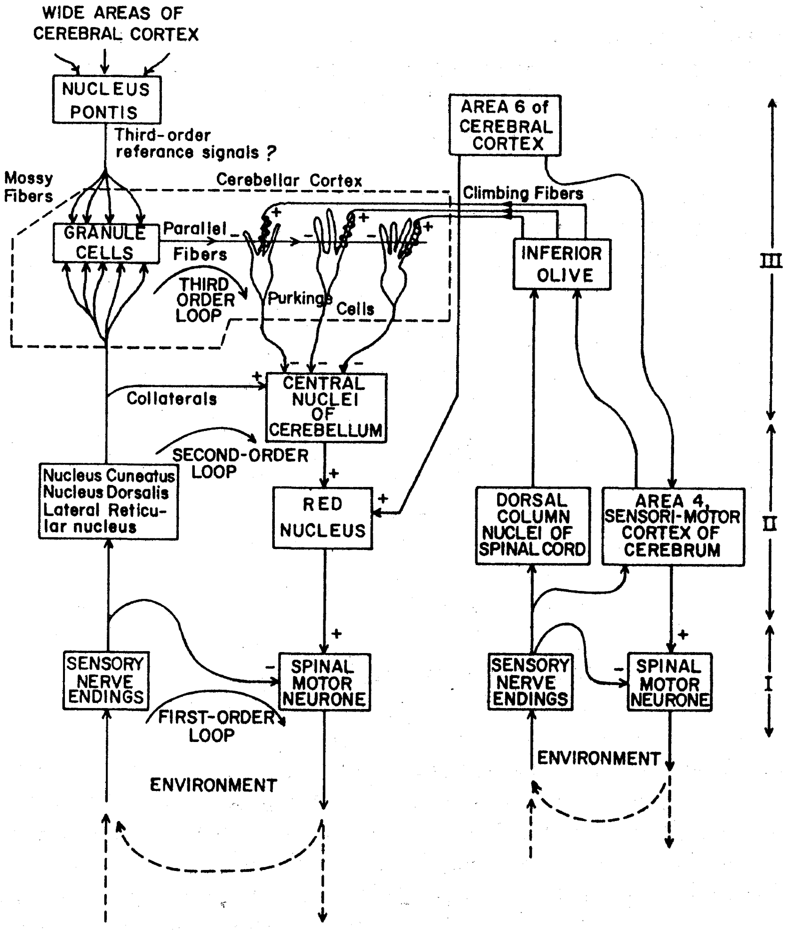


Figure 6.5 Third-order system in the cerebellum [reprinted with permission from: William T. Powers, *Behavior: The Control of Perception* (New York; Aldine de Gruyter) Copyright © 1973 William T. Powers]

figuration of the muscles of the larynx while air is being moved on through the voice box. To hold a ball, or any other object, requires maintaining a fixed configuration of the hand, once it initially has been attained. You can add many more examples.

Likewise, the higher- (fourth- and fifth-) order systems which control the shifts from configuration to configuration in sequential events, such as walking, talking, and catching flies (baseballs or bugs) also seem to be duplicated in many places in the body, with some representation in the cerebral cortex, our most recent evolutionary acquisition. Fig. 6.6 shows the cerebral cortex, with numbers indicating different areas where separate functions have been localized.

The major subdivision is between sensory or perceptual areas, in the rear, and motor or movement areas, in the front. We might guess that these two broad subdivisions could represent the input and output components of action in the external world, in other words, components of event-controlling systems. Where the circuitry of higher—more cognitive, or abstract—systems connects with these is still uncertain, as is this guess itself. (For a more thorough review of the problems of localizing brain functions, see Kass, 1987.)

The localization of functions indicated in the mappings came about initially through the observations by surgeons and neurologists of relationships between

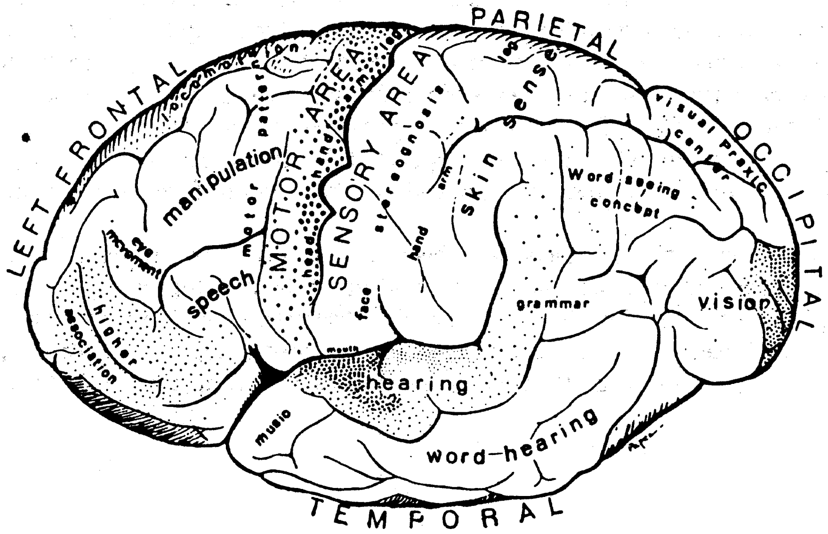


Figure 6.6 Cortical functional areas [reprinted with permission from: Ragnar Granit, *The Purposive Brain* (Cambridge, MA; MIT Press) Copyright © 1977 Massachusetts Institute of Technology]

the loss of various abilities and particular areas of brain injuries and wounds which were associated with the losses. This work has been extended more recently by direct stimulation of various brain surfaces during neurosurgery, most notably by Wilder Penfield (Penfield and Rasmussen, 1950). See Figure 6.7 for Penfield's map of cortical functional areas.

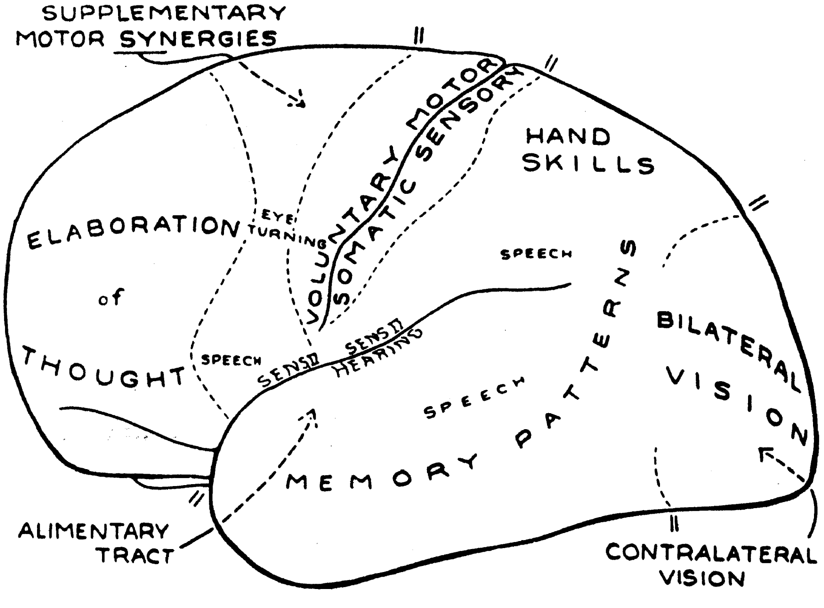


Figure 6.7 Penfield's mapping of cortical functional areas [reprinted with permission from: Ragnar Granit, *The Purposive Brain* (Cambridge, MA; MIT Press) Copyright © 1977 Massachusetts Institute of Technology]

The circuitry of the brain appears to develop through a combination of the modification of certain circuits—the "hard wiring" present at birth—and the development of new circuits in areas of the brain which may have had no specific functions to begin with. In fact, it now seems clear that many nerves die out while others add many new connections during early development (see Purves and Lichtman, 1980). The particular experiences of an individual during development seem to determine these aspects of the ultimate structure of any given person's brain, even though no new cells are believed to form in the brain after birth.

A great many detailed facts have been discovered in recent years which will eventually enhance greatly our understanding of the development and workings of higher-level control systems in the brain. Discoveries are being made at such a rate that probably no one has yet come near to putting together all of the pieces currently available so as to greatly enhance our current picture of how it all works.

Chapter 7

How Behavior Becomes Organized

7.1 Introduction

Chapter 5 presented Powers' most recent tentative model of the control-system hierarchy of a fully developed human being. How does that system develop? The field of developmental psychology is concerned with the description of the increasing complexity of overt behavior as the human organism grows into maturity. But it relates the development of behavior to its "psychic" mechanisms, leaving the discussion of the development of neuron circuitry mainly to the field of biopsychology. This latter field, on the other hand, investigates brain development with only the barest beginnings of relating it to overt action. Such connections began to be explored in "evoked potential" studies. Evoked potential studies attempt to isolate specific patterns in EEG tracings associated with single overt "behaviors," using special techniques to tease out the pattern of interest from all of the other "squiggles" in an EEG tracing.

For example, in one such study (Shucard, Shucard, and Thomas, 1977) the experimenters used "evoked auditory potential" measurements to test the hypothesis that random clicks superimposed on either a verbal task—listening for "key" words in a speech—or a musical task—listening for a melody in a musical piece—would show a larger brain wave in the right hemisphere for the musical task and a larger wave in the left hemisphere for the verbal task. They found evidence for their hypothesis, thus adding support to the view that the left hemisphere of the brain controls sequential activities like the train of words in speaking, while the right hemisphere controls global activities, like the melodic "figure" of music.

Considering the above example in the light of Chapters 4 and 5, you can imagine how some particular behavior is produced by a complex control-circuit of nerves. You can speculate that it would change the shape of a brain wave tracing when any particular circuit is activated. Then imagine how the EEG waveforms might be blends of many such circuits' waves, all acting at the same time, as EEG researchers have long suspected. How do such circuits come to be organized in the first place? Powers (1973) proposed a general model for the development of the kind of control hierarchy we discussed in Chapter 5. The newborn, lying in his or her bassinet, has, as far as we know now, all the brain cells he or she ever will have. But obviously, he or she does not have control circuits for even such a seemingly elementary task as tracking a moving object with his or her eyes beyond a narrow span, as Piaget (1965) noted.

What must come next is the organization of masses of originally "uncommitted neurons" into control circuits (see Hebb, 1949; Konorski, 1967; Horn, Rose, and Bateson, 1973; Purves and Lichtman, 1980; and Kandel and Schwartz, 1982). How they become organized clearly depends upon "experience," but how can experience occur before anything happens? This problem appeared to be a vicious circle until Powers' (1973) model showed that the first movements of the voluntary musculature must be random movements. They must be random because if every "need" of a newborn could be satisfied by an action for which the "recipe" were already stored in the brain, then there would be no need for learning, no need to organize new control circuits in the brain. On the other hand, if the "right" circuit does not already exist, and there is no "little man" in the newborn's brain to tell him or her when and how much to contract an arm, leg, or eye muscle, then there is only one possibility left: something must begin sending random signals for tensing muscles arbitrarily, which only stop when something happens satisfying the system giving rise to those arbitrary signals —that is, satisfying a "basic need."

To restate the abstract concept of the last paragraph in concrete terms, consider again the case of the newborn lying on his or her back in the bassinet, waving his or her arms around randomly. If you stop to think about it, you probably have observed this at some time or other. As long as the infant's hands do not make contact with anything but the air around them, the sensory receptor nerve endings in the skin of the fingers and hand send an unchanging pattern of signals. But as soon as a hand encounters an obstacle, say a string of gadgets hanging over the bassinet, the pattern of signals is changed. Sensory nerve endings for pressure and other first-order signals are triggered by the changed conditions. At this point, the random movements may stop for a while. Several events may be occurring. The new signal pattern may be stored in memory. The system sending arbitrary signals to the motor areas of the brain may reduce its output, for reasons to be given below. If the signal pattern of this new "event" is stored in memory, then it has become a *perception*.

That is organization.

If the muscles fatigue and the child's hand falls away, but "he" or "she" (a higher system) then wants to restore the perception of the contact with that "object" (the hanging gadget), the higher system must signal the place in the brain where that perception is stored, in order to reset it as a reference signal for the systems moving the arms. Then the child's hand moves back to where it was. As the child reexperiences the pattern of sensory signals of that original "perception," the event which had resulted from random movement in the first place is now in the process of becoming a "voluntary" act. In fact, I (RJR) have seen infants do just that: repeat an action or movement which occurred seemingly by chance the first time, as if enjoying the "feel" of causing it to happen.

We must pause a moment in this discussion to clarify the expressions "he" and "she" in the above paragraph. You may have felt that we were introducing a "little person in the brain," after saying previously that there is none, when we claimed, "'he' or 'she'... must signal the place in the brain where that perception is stored...." Obviously, to say that "he" or "she" means the child as a whole organism is not satisfying, even though trivially true. It is not satisfying because it does not indicate what the mechanism is—it does not show how it is done in the brain. Powers' (1973) answer is that it is done by a system in the brain which is there to begin with, a genetically provided system which we shall call the Organizing/Reorganizing System.[1] The function of this system is not to control perceptions as the learned control hierarchy does. Its function is to *create* the learned control hierarchy. Powers says that "it is a process akin to rewiring or microprogramming a computer so that those operations it can perform are changed... [it] alters behavior, but does not produce *specific behaviors.*" (Powers, 1973, p. 179)

It does so by generating signals which course through the motor areas of the brain, resulting in random changes in the neural impulses going outward to the systems moving the body, leading to apparently random movements. Once a movement (consisting of a *pattern* of signals to all the different muscles involved) has been stored in memory as a whole unit—as a "perception"—the memory analog of that pattern becomes available as the reference signal for future *voluntary* reactivation of that perception.

What turns the Organizing/Reorganizing System on and off? Since it clearly cannot be operating all the time, because to do so would interfere with intentional action, there must be a mechanism by which reorganization is halted. Powers proposes that "it must be of such a nature that it could operate before the very first reorganization took place, before the organism could perceive anything more complex than intensities... it senses the states of physical qualities intrinsic to the organism, and... controls those qualities with respect to genetically given reference signals." (Powers, 1973, pp. 182-183)

In other words, "... each intrinsic quality has a genetically preferred state... [which provides] the reorganizing system with *intrinsic* reference signals." (Powers, 1973, p. 184) These genetically determined reference states are the "natural" quantities for life-support conditions in each species, such as a body temperature of 98.6 degrees F in the human, and other conditions such as the optimal levels of various electrolytes, gas concentrations, and so on—the conditions necessary for maintaining life—for which neuroanatomists have found "gauges" in the hypothalamus of the brain.

The Organizing/Reorganizing System "senses the set of quantities in question.... When there is a difference between sensed intrinsic state and the intrinsic reference signals, some device must convert this difference into action... such as to change the properties of the behavioral systems." (Powers, 1973, ibid.) Thus, the Organizing/Reorganizing System is turned on when the systems monitoring conditions necessary for life register "readings" outside their tolerance limits. "In brief, intrinsic error drives reorganization." (Powers, 1972, p. 185)

To illustrate the concept above in concrete terms, consider the infant lying in the crib with a wet diaper creating error messages in temperature-control systems. He or she is thrashing about and squalling. Mother, experiencing error signals in a genetically pre-wired "baby-sounds monitoring system," tries one thing after another, until she perceives the squalling to cease. Say she is a new mother having this experience for the first time. She might come out of it having organized a program for searching out the particular "cause" of the child's squalling (in many different situations), or she might come out of it having organized a new *principle*, such as "the kid hates to be in a wet diaper," which will provide a reference signal to her diapering-program the next time the child is squalling and wet. The child might come out of the experience having organized a relationship between turning on his or her squalling system and then perceiving dryness and/or movement, warm touch, soft sounds, and the like.

What remains now is to show how the output of the reorganizing system affects the quantities it senses in such a way as to reduce the intrinsic error to zero. We think this step provides a new point of view about learning. Clearly, the way an organism behaves, or fails to behave, has indirect effects on its intrinsic state: the organism will feed itself more or less well, indulge in more or less fatiguing activities, and so on. If behavior is reorganized, the hierarchy will carry out its control activities in different ways, having different consequences on the intrinsic state. These consequences need have nothing to do directly with the kind of behavior involved; there may be many hidden connections between action and physiological result, of which the individual never knows anything. Nevertheless, changes in behavior organization will affect the intrinsic state of the organism: there is feedback...

> If there is intrinsic error, behavior will undergo continual reorganization. Control systems will alter their characteristics, controlling new perceptual varables in new ways, and this process of reorganization will continue until intrinsic error drops to zero....
>
> Intrinsic error is self-correcting simply because reorganization is in principle capable of altering any behavior pattern, and these alterations are terminated by the behavior pattern (if one exists) that succeeds in restoring intrinsic error to zero... provided that the organism does not die before the (proper) behavioral organization occurs that restores intrinsic state to its reference level.... The behavior pattern that reduces intrinsic error to zero stops the process of reorganization, and therefore, *that behavior pattern will persist*. (Powers, 1973, pp. 182-186)

Of course, the Organizing/Reorganizing System does not sense behavior or the effects of behavior upon the environment; it senses error signals coming from the monitors of intrinsic states. Thus, the process of reorganization is independent of the behavior which is being created. The organizing of new neural connections, making new behavior possible, shuts down when anything happens to reduce error in the intrinsic monitoring systems. The shutting down of the reorganization process leaves the circuitry of the brain in whatever was its arrangement when reorganization ceased.

Reorganizing may terminate when a person solves a problem, or retreats and gives up trying to solve a problem (if giving up is followed by a decline in intrinsic error). In the latter case, the individual may have organized for failure. Reorganizing also may terminate when external conditions change so as to result *coincidentally* in reduction of intrinsic error. (Thus, it is possible for reorganizations which are not optimal to be preserved at times.)

In this view, behavior has two apparently different effects, although the second type of effect is connected indirectly to the first type through a chain of circumstances. The first type is *sensory*: behavior changes the condition of the environment so that the sensory receptors of the body which report the condition of the environment will register an altered state of affairs. The second type of behavioral effect is *physiological*: if a new behavior impacts upon the environment in such a way that nutritional, respirational, and other physiological functions are modified, then the Organizing/Reorganizing System will be affected, either to increase or decrease functioning, depending upon whether the physical and biochemical changes in body functions have resulted in increased or decreased errors in the intrinsic system.

Thus, the behavior of finding, taking, tasting, and eating food involves control of the perceptions of each of these "acts"—recognizing the appearance, taste, and smell of the food, and controlling its position and relationship to one's organism. The same action, "eating," results in biochemical changes which alter intrinsic quantities pertaining to nutrition, and by that route can affect intrinsic error, and hence reorganization. The relationship between the Organizing/Reorganizing System and the learned neural-control hierarchy can be depicted as in Figure 7.1.

The loop in Figure 7.1 is closed through the environment via the effects of behavior on the physiological intrinsic values. This model is speculative, and needs future research to illuminate just what the processes of organizing brain circuitry are. But it is useful both to guide the kinds of questions which should be put by biopsychologists in their study of brain development and function, and as a means of organizing observations and facts which we already have.

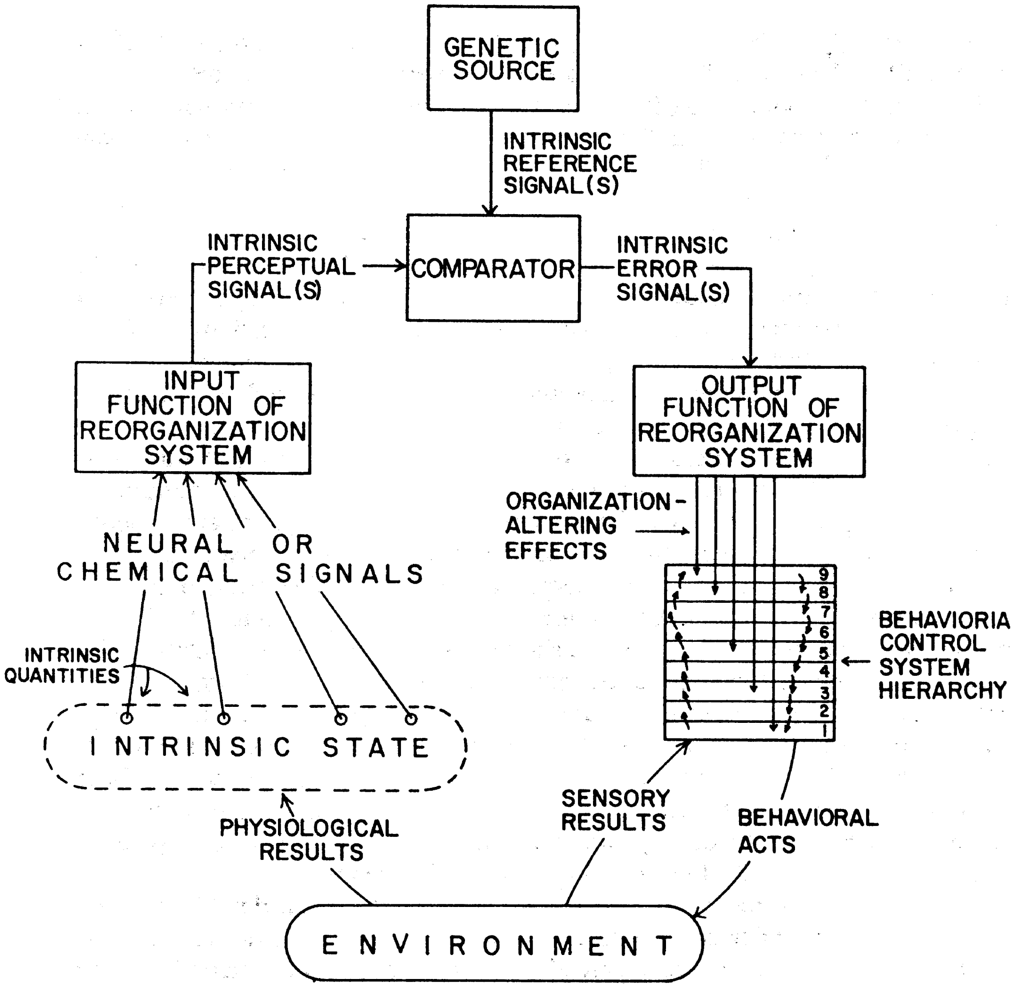


Figure 7.1 Relationship of the reorganizing system to the behavioral hierarchy and the environment [reprinted with permission from: William T. Powers, *Behavior: The Control of Perception* (New York; Aldine de Gruyter) Copyright © 1973 William T. Powers]

We shall illustrate the latter point with a hypothetical example of reorganizing helping us to understand the model, and at the same time offering a possible explanation of some previously difficult-to-understand observations. It concerns the case of a person who, not knowing how to swim, falls into deep water. Depending upon the beliefs and attitudes which the person holds as part of his or her learned control hierarchy, the autonomic "fight/flight" sympathetic system is likely to be triggered almost instantly. It probably would be triggered even before the hypothalamic monitors of carbon dioxide and oxygen levels in the blood begin to send error signals as a result of deviating from their genetically set reference condition.

The triggering of the sympathetic system is known to result in the secretion of hormones which ready the body for concerted action. Until now, no one ever has asked whether the triggering of the sympathetic system might be one of the mechanisms of reorganizing. No one has asked that because this model has not existed until now, and the prior theories of behavior did not suggest the question. The sympathetic system appears to have the required properties of an intrinsic-error response system. Here is a potent question for future research.

However, what you can see, if you are ever in a position to observe someone in water over his or her head, is flailing and struggling which has all the appearance of random behavior. This is what the model predicts. There is another potential observation which to our knowledge has never been reported—because without such a model, no one would be likely to notice it, even though they were "seeing" it. The speculation is: in an adult human—who is already able to walk, run, climb, and jump—shouldn't we expect to see learned "escape" programs employing these movements? Such would result from random actions at higher levels—trying to find a movement pattern to reduce the intrinsic error of oxygen deprivation, etc. But the actions themselves would be executed by the lower levels operating in running, climbing, and jumping.

Drawing upon our understanding of the level of "relationship control systems," the most likely first candidate among the above movement patterns is climbing. The person is in the water—below—and can perceive the air he needs as above, and since "getting from below to above" ordinarily means climbing, we might suspect that before the Organizing/Reorganizing System is fully "cranked up," the learned hierarchy already would be trying out behaviors in the person's repertoire. Thus, first you should see climbing motions. Only as the learned repertoire failed to produce reduction of intrinsic error (oxygen-deficit error) would the Organizing/Reorganizing System begin to inject bursts of signals into the brain. That would result in the breakdown of recognizable movement patterns into random movements. If, however, some subset of these random movements happened to be just the right ones to get the person's head above water for a gulp of air, and if he or she then repeated that pattern, observers would say, "That person has just learned to swim."

There are stories to the effect that, in fact, some people who did not know how to swim did learn under conditions somewhat like this. We do not recommend this as a teaching device, however: recall that, "If there is intrinsic error, behavior will undergo continual reorganization... and this process... will continue... provided that the organism does not die before the (proper) behavioral organization occurs that restores intrinsic state to its reference level." (Powers, 1973, pp. 186) If humans could go without a breath for, say, half an hour instead of just three or four minutes, then the chances for the proper random behavior to occur would be better.

At the end of Chapter 2, we proposed a new way for psychology to proceed in developing as a science. We proposed to follow the example of modern physics, by creating and testing a model of the organism. Now we turn to the process of testing the model. Scientific procedures for testing a model include inferring predictions of new facts from the model, and then looking for those facts in nature by conducting experiments in which they can be observed.

Before moving to pure experimentation, we must formulate questions about what facts to look for. Some of these facts may already exist. The needed experiments have in some cases already been done; even though they were not done with the model in mind, they may nevertheless help to test it. There has been an explosion of discoveries about the development and functioning of the nervous system in the last decade. We shall review some of these findings for evidence, and we shall also frame new questions in biopsychology which derive from the control-theory model. Students looking ahead to doing psychological research should be alert to such questions. You might find yourself prospecting new veins of gold for future careers in psychological research.

What evidence is there for an Organizing/Reorganizing System pushing the development of a learned control hierarchy? This general question can be broken down into more specific questions:

(1) What evidence is there for an "intrinsic system" of genetically determined reference signals in "life support" control systems?

(2) What evidence is there that, if an "intrinsic system" exists, it activates the control hierarchy (the learned systems) when intrinsic states are going into error?

(3) What evidence is there that error states in an "intrinsic system" can lead to new behavior by activating random action in the learned hierarchy?

(4) What evidence is there that neural circuits do become organized into complex control systems out of initially unorganized neurons?

(5) What evidence is there that new circuits can be organized by the reorganization of prior circuits?

7.2 Evidence for the Intrinsic System

The answer seems to be, yes, there is evidence of an intrinsic system. We shall consider the physiology of the regulation of food, water, and body temperature for evidence that these essential life-maintenance requirements are controlled by complex feedback systems. We have included what is known about how body temperature is maintained because, quite obviously, it is maintained within tight limits which clearly seem to have been preset by genetic determinations.

You will find yourself making use of what you have learned about the feedback model in prior chapters, because the evidence was gathered mainly by investigators holding to the S-R paradigm. Even though many investigators are beginning to see life-maintenance functions as controlled by feedback systems, the facts are usually presented in fragmentary fashion as far as the components of feedback control loops are concerned.

Let us look at how fluid levels are maintained within the body.

(1) Water Regulation. If we begin looking for the sensors which give rise to the feedback signals reporting on the level of body fluid, we find that at least three or four types could be involved. *Osmoreceptors*, nerve cells which seem to be activated by decrease of osmotic pressure, tentatively have been pinpointed in the lateral pre-optic area of the forebrain, closely associated with the anterior hypothalamus. (Blass and Epstein, 1971; Peck and Novin, 1971; and Jewell and Verney, 1957) *Baroreceptors*, located in the walls of the left atrium of the heart, detect fluid volume loss in the blood. *Kidney vessel receptors*, which may comprise part of the input function of a first-order circuit, control release of a set of hormones which are "read" by receptors in the hypothalamus. *Sodium receptors* sense sodium ion concentration in the tissue fluid.

The hypothalamus appears to be a collection of nerve centers supplying genetically set reference signals, also called "set points" by some investigators. The outputs of these intrinsic systems are biochemicals (proteins, hormones) and muscles which tighten or loosen around small blood vessels to increase or decrease the flow of blood. These control systems qualify quite well as first-order systems, because they seem restricted to varying the magnitude (or intensity) of just one variable. One type seems to increase or decrease muscle tension around blood vessels, thereby regulating many tiny areas of blood flow; another type seems to increase or decrease the secretion of a particular hormone. Several such systems appear to be coordinated within higher-order systems which result in the sensation of thirst and/or in various fluid conservation measures, such as decreased urine secretion and redistribution of existing fluid supplies. (For greater detail, see texts on physiological psychology, such as McFarland, 1981, or texts on neurophysiology.)

The facts gathered by experiments to date suggest that the comparators, and probably the reference signals, of many (if not most, or all) intrinsic systems are located in and around the hypothalamus. How do we know that the reference signals, and not some other components of the control loop, are located there? Experiments in which portions of these areas were destroyed resulted in ceaseless drinking (and in other cases, ceaseless eating). This result would occur if a comparator is putting out a never-ending error signal, either because the feedback signal is not arriving for comparison, or because the reference signal is not supplied.

(2) Regulation of Food Intake. As with control of fluid intake, food intake has been studied by experimenters whose search for facts was guided by a stimulus-response paradigm. It is difficult to sort out the facts discovered so far into the geography of feedback functions, comparator functions, error signals, and output functions. The results of the output function are, of course, the familiar acts of noticing, selecting, reaching for, and taking food into the mouth, then chewing and swallowing. In addition, there is the secretion of digestive juices, beginning with saliva and including stomach digestive chemicals such as pepsin, and the mechanical outputs such as the muscular contractions of the stomach and intestinal walls.

But where does this process begin? We perceive food with heightened interest under several different conditions: at rhythmical intervals; when "feeling" hungry; in certain social situations; often even without feeling hungry. If we regard this variety of experience from the vantage of our model, it seems probable that each type of condition, except the sensation of hunger, is more likely an indication of variations in reference signals than in feedback signals. Why? Because it is improbable to conceive of a sensor for, say, low-blood-sugar-in-the-presence-of-your-best-friend. It seems more probable that the feedback signal indicating the current level of blood sugar would result in a larger or smaller error, depending upon the setting of the reference signal under the various conditions created by different activities.

Then where are the sensors for hunger located, of what kind are they, and where are the comparators to which they report located? Several pieces of evidence, taken together, suggest that at least one type may be located in the brain, specifically in the walls of the small blood vessels supplying the ventro-medial hypothalamus. Here is how the reasoning goes. A drug, 2-deoxy-D-glucose, which competes with glucose to occupy receptors on cell membranes, was injected into the hypothalamus. The result was increased feeding (Houpt and Hance, 1971). High levels of glucose in the blood entering the brain are accompanied by increased electrical activity in the ventro-medial hypothalamus (Anand, Chinna and Singh, 1962). Injections of gold thioglucose[2] into the blood vessels supplying the ventro-medial hypothalamus resulted in its destruction, followed by overeating, suggesting that feedback signals were lacking to indicate the presence of glucose (Epstein, 1960; Mayer and Marshall, 1956).[3]

Where are the comparators for glucose supply located, and from where do they receive their reference signals? The answer to the first question appears to be the hypothalamus. Electrical stimulation of the ventro-medial hypothalamus results in decreased feeding, and electrical stimulation of the lateral hypothalamus results in increased feeding. We are assuming that electrical stimulation duplicates the action of feedback signals which normally come from the sensors described above.

Where are the reference signals originating? We should look for a hierarchical model. We must start by applying logical analysis to the facts which are known. The lowest-order reference signals should specify a range—not too much, not too little—of their sensor readings. Take, for example, control of glucose, since the evidence appears strong that the level of this substance is a controlled variable in humans. Logic suggests that the amount of glucose "to be sensed" is set by a higher-order system; otherwise glucose would be as tightly controlled as is, for example, body temperature, and there would be no need for a desire for sweet tastes. As it is, we know that the "taste" for refined sugar can be set higher than is healthy for a person. In primitive, "natural" living conditions, the desire for sweetness probably would not ordinarily expose a person to an oversupply of various sugars. That suggests why previous evolution did not lead to setting an upper limit; it wasn't necessary for survival under most primitive conditions, and hence genetic mutations with upper limits would not have been selected preferentially.

We also might expect that the reference signals for various tastes—what we experience as "desires" for those tastes—originate in or around the hypothalamus and hypothalamic-limbic system connections, close to where the comparators seem to be located. As to how they work, we are dependent upon even more speculation. They may be built into the sense receptors, just as the feedback and comparator functions are combined in the bi-metal strips in home thermostats. When a taste receptor has all of its terminals occupied by the molecules to which it is receptive, this may constitute the reference signal "enough." Or the rate at which the receptor is binding the molecules to which it is sensitive may interact with chemicals produced by genes within the cell to raise or lower its rate of firing.[4]

To understand the statement above, recall the work of Koshland (1980) on single-celled organisms. He found out how the chemoreceptors of simple organisms "count" and report the counts of nutrient molecules which they monitor, by metabolizing proteins which act as detectors for various nutrients, with only the right nutrients fitting the "keyholes" in the surface membrane of the organism.[5] The organism is constructed in such a way that it can keep moving in the direction in which it finds food. Koshland states: "Between the receptor and the motor, however, the initial signal must be processed so that the stimulus can be correctly interpreted.... This processing system is more sophisticated than the casual observer might expect and also more similar to the organization of higher species."[6](1980, p. 55)

The most important thing to note is the similarity in the way the concentration of a given chemical provides information about the environment in organisms all the way from bacterium to human. Bacteria have receptor sites for specific chemicals, relevant to their existence, in their cell membranes. Higher organisms have specialized nerves containing receptor sites for chemicals—relevant either as nutrients, or as means of keeping track of or transmitting information—in their membranes. They work in the same manner: by the binding of the particular molecules in question to the receptor site. The influence of genes in providing intrinsic-system reference signals seems likely to be similar: by controlling the way in which given rates of neurotransmitter and metabolic substances arriving at receptor sites are "read" as too little, too much, or just right. We shall take up the discussion of how intrinsic-system monitoring of *chemical reactions* ultimately is involved in the control of the movements in the "actions" which we call behavior, after considering one more intrinsic regulatory system.

(3) Control of Body Temperature. Temperature control provides us with a superficially different kind of control system, in that it monitors a condition instead of substances, a quality rather than a quantity. Nevertheless, control is very tight, which seems to indicate that a species-specific, genetically determined reference signal indeed is involved. As with the other intrinsic system variables, current researchers have located thermoregulation in the hypothalamus. J. A. Boulant, reviewing what is known about temperature regulation (in the *Handbook of the Hypothalamus*, Morgane and Panksepp, 1980) remarks, "In reality, a vast neuronal network extending throughout the hypothalamus and related structures regulates the body's entire internal environment, both autonomically and behaviorally. The separation of the thermoregulatory system from all other regulatory systems is a separation necessarily contrived for simplification." (p. 82) We might take this observation as support for locating the intrinsic system in the hypothalamus. Boulant does point out that other peripheral, spinal, and brain stem structures also are involved, but he sees the hypothalamus as "integrative." That alerts us to look for evidence of comparators receiving gene-initiated reference signals there. Let's see what we find.

Hammel (1965) is credited with proposing a model built around recently discovered "hypothalamic temperature-sensitive neurons." Two different types of "thermosensitive neurons" have been found in the preoptic/anterior hypothalamus area. Some (called "high Q10 neurons" in the research literature) were found to be highly variable; they increase firing rate when the tissue is warmed (with a special kind of probe) and decrease firing rate when the tissue is cooled. Others (called "low Q10 neurons") are known as "temperature-insensitive neurons," because they show little change in firing rates when the hypothalamus temperature is altered. Hammel's model regards these two types of neurons as sending "mutually antagonistic synaptic inputs to each of the effector neurons. This antagonistic input then determines the firing rate in each effector neuron." (pp. 71-72) This picture of a constant being subtracted from a variable to produce changes in signal rates is what we call a *comparator*. We think Hammel was looking at neurons supplying feedback signals (high Q10s), neurons supplying reference signals (low Q10s), and neurons carrying error signals (the "effector neurons").

Consider a further fact provided by Boulant: "Prior to Hammel's model, single-unit studies in cats had actually identified these two types of sensory neurons (Nakayama, et al., 1963). Out of more than 1000 neurons recorded in the anterior and posterior hypothalamus, about 20% were considered to be warm sensitive and the other 80% were considered to be temperature insensitive." (pp. 1122-1126) Why are there so many more reference-signalling neurons than feedback neurons in the hypothalamus? We can offer a plausible hypothesis: Only a few of the body's temperature sensors would be expected to be located in the hypothalamus (to monitor blood temperature in the brain); the rest would be located throughout the body. But most of the reference-signalling neurons should be located in the hypothalamus, if the comparators are located there.

Boulant went on to review the evidence that the hypothalamic centers are involved in controlling reference signals of other systems in the body (including, for example, muscles initiating shivering). We shall not review all these details here, because we are considering the facts with regard to the question of where we might find the "intrinsic system" in the body. We shall mention one more fact, reported by Myers (1980): "....disseminated bilateral ablation of the posterior hypothalamus destroys the animal's capacity to maintain its body at a stable temperature in either a cold or warm environment (Keller, 1933)."

We have one final point to consider. How might genes be involved in initiating the intrinsic reference signal for tight control of body temperature? Myers (1980, p. 135) provides as much of an answer as presently exists: "...the set point [read "reference signal" (RJR)] has been defined in physiological terms as that reference temperature of about 37 degrees C, established at birth in most mammals, around which body temperature is regulated... the steady-state firing pattern presumably required for a set point [appears to be located in the posterior hypothalamus].... The ionic milieu in the caudal hypothalamus... stable under normal circumstances, would seem to provide an ideal mechanism whereby a reasonable stability in temperature could be achieved."

We are not aware of any research which bears directly on the question of how the genes are involved in this steady state, however, Myers (1980, pp. 135-137) reports studies showing that a very precise balance between sodium and calcium ions is maintained in the cells of the posterior hypothalamus. One guess would be that this balance is maintained by gene control of the metabolism of these cells, much like that described by Koshland (1980) in the microorganisms he studied.

7.3 Intrinsic System Involvement in Learned Actions

We take it as common sense that much of our behavior is at least distantly connected with maintaining the necessary conditions for the cells within our bodies to keep on living. We perform the programs of our occupation ultimately to put food on the table, and, even more ultimately, to insure that the comparators monitoring nutrients and electrolytes will be satisfied.

However, traditional psychology, with its basic concepts of reflexes and associations, has led us to keep trying to break the actions of the organism into separate mechanisms, thereby making it difficult to keep in mind that the central nervous system is constantly working as a whole. Thus Boulant, describing the mechanisms of temperature control, says, "A constant body temperature is maintained by a wide variety of physiological and behavioral responses. The hypothalamus has some control over each one of these responses." (Op. cit.) It is involved in calling for increased heat production through the burning of fuel, as in shivering; by minimizing heat loss, through shunting blood away from the surface of the body, and by learned behavior, such as putting on a coat. In the latter instance, we finally come to the observation that "the hypothalamus is an important structure in the limbic system, which is responsible for emotions and motivated behavior, as well as learning." These areas receive temperature feedback signals from the periphery of the body—thus we can begin to understand how a person might put on a coat long before he or she begins to shiver, even though shivering is a more "physiological" mechanism.

The explanation would be that the lower-order inputs don't go *only* to the intrinsic-system centers in the adult, as they might have in the infant. They also send feedback to subsequently acquired systems, such as the system which controls the sequence of body movements by which you put on a coat. That sequence-control "subroutine" might be included in several different programs, so that it is a different thing to put on a coat because you are cold than it is to put on a coat because you are going to talk to your boss.

In physiological terms, even though you may "call up" exactly the same muscle tension "readings" when you put-on-a-coat-because-you-are-cold as you do when you put-on-a-coat-because-you-are-going-to-talk-to-your-boss, only those portions of the neural circuit are the same. All other parts of the circuit (or many of them, at least) are different.

Boulant (1980), in discussing the hypothalamus as a limbic structure, the whole of which is "responsible for emotions and motivated behavior, as well as learning," says: "Just as these limbic areas determine the pleasantness or unpleasantness of cutaneous tactile and noxious stimuli, so too these same hypothalamic areas may determine whether or not a particular skin temperature is considered comfortable or uncomfortable.... If a skin temperature is 'emotionally' considered to be uncomfortable, then, by ascending and descending limbic signals, an appropriate behavior is employed to make skin temperature more comfortable. If this is not possible, then the appropriate autonomic responses are employed to insure that core temperature remains constant despite the change in skin temperature." (Ibid.)

7.4 Intrinsic-System Error and Reorganization

What evidence do we have about whether the intrinsic-system does in fact amplify spontaneous activity in the motor areas of the brain when intrinsic error cannot be reduced? This suggestion of Powers' model appeals to common sense, in that it would seem to provide an explanation for the kind of struggling which we sometimes see in various emergency and panic situations.[7] For example, consider once more the person in deep water, who does not know how to swim. Is such action missing in people who are starving or dying of thirst? In those cases, we do not find wild, panic behavior, but previous research *has* demonstrated random action spread out over a longer time span. Error signals presumably mount up more slowly in these conditions than under oxygen deprivation, and perhaps by the time hunger or thirst would result in wild thrashing about, the depletion of physical strength has gone too far to permit it.

What do we know about the actual mechanism for increased random action in the motor areas? We must piece together a mechanism from a number of isolated bits of information. First, there is the general fact that "even many normally quiescent neurons can be made to give rise to spontaneous potentials." (Bullock, 1977, p. 153) This happens as a result of changes in the chemical environment of the cells. Next, the reticular formation of the brainstem is known to affect the state of activity of the entire nervous system, or selectively increase activity in a particular circuit. (Op. cit., p. 323) So-called "drive centers" (where specific muscle action sequences are believed to originate) are known to be "active in proportion to some internal state, such as glucose titer or hormone level." (Op. cit., p. 320)

Tracing backward to the hypothalamic intrinsic state monitors, we speculate that error signals originating in the hypothalamic comparators increase signalling to limbic and reticular areas, where increased motor area activity is amplified. An extreme case of motor activity amplification, the epileptic seizure, seems frequently to begin in the hippocampus, one of the limbic system areas, or in the nearby temporal neocortex. These areas have been found to generate spontaneous signalling in individuals suffering from this condition, but it is not clear what conditions are necessary to get it started. The chemical environment is one candidate (see Schwartzkroin and Knowles, 1984; Aldenhoff, Gruol, Rivier, and Siggins, 1983).

A fertile area for future research would seem to be investigation of possible links between life-maintenance "emergencies," autonomic nervous system "fight or flight reactions," and spontaneous increases in activation of the entire nervous system.

We have seen that a good case can be made for locating the control of intrinsic, life-maintenance activities in the hypothalamus and surrounding structures of the "old brain." There is considerable evidence that these structures interact with the reticular activating system, where signalling activity is increased and decreased, and with the turning on and off of the two branches of the autonomic nervous system. The sympathetic branch of the autonomic system mediates increased effort in various types of activity, while the autonomic branch seems involved with turning down effort, relaxation, and "consummatory" actions such as eating.

We seem to have all of the ingredients for an Organizing/Reorganizing System here; however, it will require future research to formulate and test the questions about the involvement of these systems in the development of control systems for complex behavior.

The last two of our critical questions, "Do circuits develop among uncommitted neurons as a result of initially random activity?" and "Do existing circuits become reorganized into new circuits under any conditions?" we shall leave to Chapter 8. These are the problems of the neurology of learning.

Notes

1. Powers (1973) called this system the "Reorganizing System" when he introduced it, which is technically correct, because every change in circuitry in the brain must be a *re*organization of what it was previously. However, in my (RJR) work in teaching, rehabilitation, and research on learning, I have found that it is generally much easier to learn something for the first time than to learn something in the same area in which one already has systems for controlling the variables in question. Many remedial and rehabilitation workers of my acquaintance have made this same point. I believe the reason is that the existing systems go into error states, and their attempts at correction then interfere with bringing the new and different perceptual values under control. This is the phenomenon termed "resistance" in psychotherapy by Freud, in my opinion.

2. Which is taken up by glucose receptors, but kills cells which absorb it.

3. Not all of the sensors for blood sugar appear to be located in the blood vessel walls leading to the VDH, however. Other findings have shown that 2-DG, which can displace glucose on receptors, results in decreased feeding when injected into the hepatic portal vein of the liver. And injection of fructose, which cannot be used in the brain, but can be metabolized in the liver, also results in decreased feeding. Whether the feedback signals from these sensors are transmitted to the brain via hormones or neural signals is not clear.

4. If there are genetically determined reference signals for glucose and sweet tastes, it would be reasonable to expect to find them in parts of the brain which developed early in evolution, because even animals low on the evolutionary scale show tendencies toward food preferences, including sweetness. And since much recent research has shown that brain stem centers in cats, rats, and dogs occur in comparable places and perform comparable functions to those in humans, we might tentatively follow up these analogies. Laboratory animals, such as cats, rats, and dogs, have hypothalamic and limbic centers and connections analogous to those of more primitive species.

5. There are separate detectors for galactose, ribose, and maltose. Each protein has an ending to which only *one* type of sugar will attach. These sugars are considered "attractants" to the organism. There are other substances, termed "repellents," monitored by the organism by a similar method. The particular organism studied by Koshland has approximately 30 different kinds of detectors (chemical receptors) distributed over its surface membrane. These receptors transport their particular molecules through the membrane and release them. In a cell as simple as this, the just-mentioned activity constitutes both "eating" and "perceiving the direction in which food lies." The organism perceives only increasing or decreasing gradients in the concentrations of nutrients. A simplified explanation of how it does this is that the rate at which such molecules are used is affected by chemicals produced at the prior rate of usage. The organism moves in the direction of increasing nutrient concentration; when it detects a decreasing gradient, it stops swimming. It cannot steer, it can only move or stop moving and

tumble randomly, then move again in whatever direction it points when the tumbling stops. If an increasing nutrient gradient is detected, the movement continues; otherwise, tumbling occurs again.

6. A simplified version of his explanation goes like this. A group of genes within the organism control the production of molecules which connect with other molecules transported into the cell by receptors. The proportions in which they interact supply the motor apparatus (flagella) with signals causing uniform rotation to continue or reversal of rotation (causing tumbling).

7. I (RJR) wonder whether we ought to consider also in this connection states of fear or rage in which a person suddenly "goes berserk."

Chapter 8

Learning: Increasing Control Over the Environment

How do we become able to control variables which were previously not under control? In this chapter, we shall discuss the relationship between the formation of neural control systems and the concept of "association." Then we shall review some of the history of the psychological study of learning, perception, and motivation. The artificial separation of the facts into these three concepts does not make sense in the light of the control-theory model. We shall describe how different theoretical positions have affected the investigation of the facts, and we shall offer a unified explanation of these concepts from the control-theory view.

8.1 Learning as Development of Control Systems

Chapter 7 explained the theory of how new control systems develop. Powers' model postulates that error conditions within the intrinsic-system of an organism must result in increased neural firing throughout the organism's nerve network. Eventually, when intrinsic-system errors decrease, the circuit (or path of the signals) active at that time becomes a new control system to counteract such errors in the future. The new circuit is a control system for the disturbance which initiated the error condition. When an intrinsic-system error condition (such as need for water, food oxygen, or other genetically referenced life-support variables) leads to widespread signalling in the brain, it results in movements which are random until a reduction of intrinsic error occurs. Then the Organizing/Reorganizing System shuts down, the current configuration of neural circuitry is preserved, and we call the recorded action pattern "behavior."

Recall the example in Chapter 7, in which "frantic flailing about" became '"swimming" at the moment when oxygen-level error signals began to decrease. In that example, intrinsic-system errors began to decrease when the disorganized collection of arm and leg movements coalesced into the proper, rhythmically alternating pattern we recognize as swimming. While all this was happening, it also would have been necessary for analogues of the oxygen feedback signals and of the arm and leg movement sequence signals to be stored together as a unit in memory. Thus, on a future occasion (of plunging into water, for example), oxygen-level error signals could not mount up to the extreme condition of the earlier case, because before they could trigger that extreme condition, corrective action would have begun in the new control system which was built during the prior occasion.

The new control system would contain the memory of the whole collection of feedback signals stored previously. Thus, the signal analogues stored in the formative situation become reference signals specifying what the "readings" should be for the current perceptions. When the whole system obtains the right pattern of signals, behavior is again what it was on the earlier occasion. This description doesn't apply just to the oxygen control situation, of course, but to satisfaction of hunger, thirst, feelings of being too cold or too hot, and the like, which are involved in the development of new systems.

A further point, implicit in the above discussion, must now be brought out. To keep the explanation simple, we shall continue with the swimming example. Upon subsequent plunges into the water after the first, the control system called "swimming" doesn't need oxygen-level error signals to start it. When that control system was formed, feedback signals from the eyes, the ears, various skin receptors, and possibly even taste and smell receptors all were being incorporated into it. Nor were they incorporated into it in a helter-skelter fashion. The overall system would incorporate several orders or levels, as described in Chapters 5 and 6. How many levels, and just how they are organized, would vary from one person to another according to the details of the circumstances under which they were formed. Two different aspects of the circumstances would be these: (1) the repertoire of control systems already in the person at the time of learning; (2) the exact nature of the external environment at the time.

Thus, the control of oxygen-level would not involve triggering the Organizing/Reorganizing system on a second occasion, because oxygen concentration would be controlled *automatically* as a by-product of the control of higher-order variables. Correction of higher-order errors automatically prevents the original intrinsic-system error from occurring. For example, a higher-order error signal might be the feeling, "Oops, the canoe is rolling over." (And so I hold my breath and swim up to the surface.) A different example might be, "I think I'll go swimming now." Either of these would be an error signal in a principle valuing swimming at the moment, and simultaneously a reference signal for activating a swimming program.

You might wonder why we called the last example an "error signal." You are used to calling it a "wish," a "desire," or a "decision." When we look at it in control-theory terms, we see that the act of getting into the water can be an output of a very high-order control system, in which the purpose (reference signal) *to perceive oneself swimming*, if not matched by the feedback signal *I am swimming*, would be a mismatch or error, felt as something wrong. It would be resolved by turning up a program, as in "I think I'll go swimming," which in turn sets lower-order systems for the appropriate body movements. The control of oxygen-level was already included in "swimming" during the original organization of that system. The traditional term for this kind of combination of perceptual variables into more complex behavior patterns is "association."

8.2 The Traditional Concept of Association

8.2.1 Origin of the Idea of Association

As we indicated in Chapter 1, modern psychology began with Descartes, around 1650. His notion that the action of the body takes place in the form of reflexes triggered by stimuli from the environment set the stage for asking why it is that stimuli which at one time did not trigger a given reflex could eventually do so. That was the question to which Pavlov gave an answer 250 years later with his concept of "conditioning." The stage had been set for Pavlov by the English psychological philosophers, beginning with Thomas Hobbes and John Locke. Their two concepts, *empiricism* and *associationism*, were considered fundamental by a leading American psychologist, Edwin G. Boring, who said, "It is this tradition more than any other which has influenced modern psychology." (1950, p.168)

In opposition to Descartes, who thought that ideas are innate in the mind, Locke believed that ideas are derived from experience, and that simple ideas become combined into more complex ideas when two or more are in mind at the same time, or follow each other in time. He called this notion "association of ideas." It has come down into all of the branches of modern psychology. Freud based his concept of "free association" on it; he observed that one could discover connections between seemingly unrelated thoughts by noting the order in which they come to mind when not occupied by any ongoing activity.

Pavlov employed the concept of association in his notion of "conditioning," in which a neutral stimulus is thought to be welded onto a natural or unconditioned reflex by association, through occurring at the same time. Modern Behaviorism added "operant conditioning," the connection of an action and a "reinforcement," or reward, by their association in time.

Two additional concepts were developed in psychology to account for aspects of learning which remained awkward to account for simply by association. These were the concepts of *perception* and *motivation*.

Perception became a necessary concept when early psychologists noted that, if stimuli triggered their associated responses in a completely mechanical way, a person would be like a whirling dervish, since at any given time one is subject to a multitude of different stimuli. They believed, therefore, that there must be some way of separating different stimuli, and filtering out those to which the organism is not going to respond, as when a mother hosting a party suddenly stops hearing what her husband's boss is saying as she perceives the faint cry of her baby coming from another room. The psychological specialty of perception developed to investigate how the mass of stimuli from the senses comes to be sorted into the units or categories of experience.

The concept of motivation had to be invented to account for the observation that associations form more readily under some conditions than under other conditions. Thus, a rat will wander seemingly aimlessly through an experimenter's maze when fully fed, and race through it frantically when starving. The rat is said to "associate" each correct turn with the last one much more rapidly under the latter condition than under the former. The concept of "motivation" is used in the sense of pressure or force driving the rate at which learning occurs.

We argue below that these concepts are not separate processes, but aspects of the process of control which were separated out artificially as a result of Descartes' original model of behavior, in which behavior was thought to be caused by stimuli coming into the organism from the environment.

8.2.2 Weaknesses in Associationism

The concept of association between ideas made reasonably good sense as long as scientists were occupied with mental images in their attempts to build a psychology. If you pay attention to the flow of thoughts through your mind, it is readily apparent that one idea often does lead to another by way of their relation in some previous experience. Thus, if I focus my attention on the fact that I (RJR) am sitting here at the computer keyboard, I think of how I formerly would have been sitting at a typewriter. That reminds me of the frustrations I used to have, continually stopping to erase or strike over typographical errors. The idea of a word processor is associated in my mind with a more pleasurable feeling; it is also associated with the ideas of progress, efficiency, and the like.

However, association is an extremely limited concept when it comes to relating the connections which occur in learning with what might be happening in the nervous system. There is no sense of hierarchy in the concept of association. Every idea, "reflex," or act is taken as a unit by itself. This has created considerable confusion in attempts to obtain a sensible explanation of how associations occur.

One learning theorist, Guthrie (1935), offered a solution to this problem by supposing that all signals flowing in the sense receptors at the same time become associated with each other. (Notice some similarity between Guthrie's view and the control-theory position in Section 8.1.) Pavlov (1957) and others believed that associations are formed only between sensations which immediately precede a built-in (instinctive) reflex, such as salivating at the sight and smell of food.

As research in biopsychology proceeded, the confusion grew; investigators described the facts they were discovering in the terms of the traditional paradigm, without really thinking about how poorly those terms fit. In applying the concept of association to their discoveries about information processing in the nervous system, they tended to talk about how the circuit for one thing might get attached to (associated with) the circuit for another thing. For example, some researchers attempted to speculate how a circuit for seeing an object could become "associated" with a circuit for moving the arms (say, when a child sees a ball and reaches for it), as if they thought the nervous system works in terms of the way we view behavior.

There is no evidence in the unfolding discoveries about how nervous systems operate that neural circuits reflect categories of our human experience. Quite the contrary: the accumulating evidence has undermined the concept of association in a way which had not been anticipated. More and more of the descriptions of nerve regulation of bodily functioning now are being given in terms of control circuits. (See Morgane and Panksepp, op. cit.)

To see what difference that makes, let us compare the two kinds of explanation. The concept of association implies that *information* is associated either with other information (idea with idea) or with movement (perception with action). Let us review the discussion above, about the control of perceptual variables, to illustrate the difference.

Suppose I say to you, "Look closely at this printed page in front of you; what do you see?" You may be wondering what I mean by that—that is, what I intend for you to see. Do I want you to notice something about the color or grain of the paper, the shapes of the letters, the separate words, the meanings, the language, the writing style, or what? As you went through the list, you might have been aware that you could choose your focus so as to make any of those the center of awareness. To set your focus involves controlling how your eyes move; it also involves controlling the "chunking" of incoming data. If you chose to examine the letters, you might not have been able to get the meaning of the words at the same time, and vice versa.

If you try to imagine the kind of neural circuits which would be working as you shifted from one "level" of control to another, doesn't it strike you as more likely that some of the circuits seem to be *parts* of others, instead of all being separate items which get linked together under such circumstances? Unlike the model of the brain which is implied by the associationist conception, the control-theory model implies a hierarchical arrangement which envisions the integration of all lower systems by the systems of the next higher levels. In this view, learning is the *building* of such control systems, rather than the linking of pre-existing "perceptions," whose existence would then still have to be accounted for.

8.3 The Biology of Learning: Which Model Fits Best?

Does the control-theory model fit the known facts about nerve-circuit formation? Let us examine a simple case. Only within the last few years have we had any facts about what is happening when neural networks are being established. Some important information on this subject was presented in an article by Kandel and Schwartz (1982) on the "molecular biology of learning." Working with a large marine snail (genus *Aplysia*), they studied a phenomenon which they called "sensitization"—a term from traditional learning theory. They used the snail because its large, relatively few nerves made it possible to map the circuitry of a "defensive withdrawal reflex" of the animal's breathing mechanism when subjected to a disturbance. This "reflex" shows "adaptation" or "habituation." That is, if the snail's mantle (a fleshy fold next to the gill) or its gill siphon is touched, the gill will be withdrawn under the mantle. When touched repeatedly, the "withdrawal reflex" is vigorous at first, but declines in vigor with subsequent touches. This "reflex" can be "sensitized" by applying an electrical shock to the animal's tail. After that, the "withdrawal reflex" will be very vigorous for "... minutes to hours depending upon the intensity of the sensitizing stimulus." (Kandel and Schwartz, op. cit.)

We have placed the terms "reflex" and "sensitized" in quotes to call attention to the way these researchers' perception of the phenomena reflects traditional learning theory. The facts can be stated very simply in non-technical terms as follows: if you touch its mantle or siphon, the animal will quickly pull its gill down under the mantle. If you keep touching it, it will gradually cease to pull the gill down; but if you then give an electric shock to the head or tail, it will pull its gill down much more strongly again, and will continue to do so with each new touch for a long time.

Can we describe a possible mechanism for this phenomenon with the control-theory model? Suppose we call the "withdrawal reflex" simply "gill withdrawal," and attempt to see how it might work. An initial hypothesis would be that gill withdrawal is the motor output of a system controlling the environment just outside the gill. To determine the *controlled variable* of this control system, we would need to apply the test for the controlled variable. If our first hypothesis is right, then touching the mantle would not necessarily be the only act which results in gill withdrawal.

If the system is involved in controlling the water environment surrounding the entrance to the gill, there ought to be transducers for the various kinds of chemical and mechanical conditions injurious to the breathing mechanism of the organism on the input side of this system. Common sense suggests that a gill can be easily damaged, not only mechanically but chemically. Hence, it would be plausible to look not only for tactile but also for chemical and possibly for thermal sense receptors in this control system. This would require an anatomical and physiological study of the sense receptors to determine what they detect. We will table that in order to continue examining what else Kandel and Schwartz have told us about this system, to see if that information fits the picture of a control system.

Since gill withdrawal seems to be present in *Aplysia* from the beginning, it would seem to be a first-order system, somewhat comparable to the control of muscle contraction in humans. Suppose that the gill is withdrawn under the mantle, or, conversely, is permitted to pop out to the animal's surface, by a single-dimensional controlled variable: the flow of signals from sense receptors in the surrounding skin. The output side of the system would be equally simple. The gill is either at the surface or in the gill cavity, depending on the magnitude of tension in the muscle holding it in position. In that case, we are looking at variability in *intensity*. If the condition under control is the immediate environment of the gill, then the reference would be for a zero- or low-level input of any material except oxygenated water around the gill. There should be several different types of transducers (sensory receptors) testing that environment, as we stated above. The output is of a simple on/off type. If feedback increases in intensity, then the output mechanism, the muscle, withdraws the gill.

Can this system be set to different degrees of sensitivity? Clearly, it can. Repeated touching is followed by less vigorous gill withdrawal; the reference signal for first-order input is reset lower and lower. This suggests at least a second order in the system. What do the anatomical facts say about this? Examine the "wiring diagram" of the neural circuitry, as presented by Kandel and Schwartz (1982), shown in Figure 8.1.

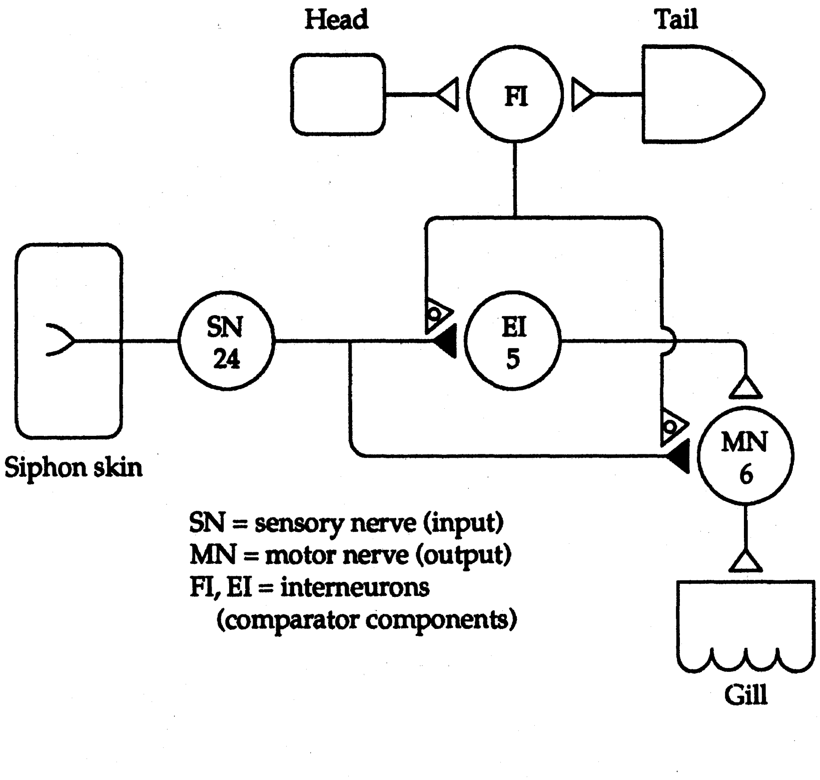


Figure 8.1 Gill Withdrawal Circuit [redrawn with permission from: E. R. Kandel and J.H. Schwartz, "Molecular biology of learning: Modulation of transmitter release," *Science 218*, October 29, 1982, 433-443, Copyright © 1982 by the AAAS]

Note that the junction at EI 5, called the "excitatory interneuron," fits the description of a comparator. At EI 5, the feedback signal from the siphon skin sensory neurons converges with the signal from FI, which occupies a position corresponding to that of the reference signal in the control circuit diagram. We could expect that the output signal from MN 6 to the gill muscle is modifiable by the output from systems involving head and tail sensory receptors. Kandel and Schwartz called the neuronal output from the higher level system a "facilitating interneuron." However, it meets the requirement of providing the reference signal coming into the comparator at EI 5, as we surmised above. The signal to this comparator is partially chemical and partially neural, according to the details worked out by Kandel and Schwartz. In its initial, unmodified state, the comparator function seems to be incorporated in the built-in amount of transmitter chemical released by the sensory neuron synapsing with EI 5. Repeated signalling along SN 24 is accompanied by decreasing amounts of transmitter release, which implies a decreasing reference signal, resulting in a diminishing error signal from EI 5 to MN 6, the motor nerve for the muscle withdrawing the gill. This is the mechanism of "habituation" or "adaptation."

Signals from the "facilitating interneuron" can raise the error signal from EI 5, resulting in increased output from MN 6, leading to stronger gill withdrawal. It *facilitates* in the sense of turning up the sensitivity of the first-order system.[1]

The question remains as to the function of the cell labelled EI 5 in the diagram, since sensitization of the sensory-motor first order synapse can be effected directly by the FI neurons. An earlier report by the same team (Kupferman, Castellucci, Pinsker, and Kandel, 1970) reported that cells of this type synapse with several motor neurons at once. If they also receive feedback signals from several sensory neurons, then they could serve as second-order comparators, coordinating the withdrawal of all the organs of the abdominal cavity, which does occur, according to the investigators.

The diminishing error signal described above produces the phenomenon traditionally called "adaptation." Adaptation is defined as a diminishing response to a stimulus. Adaptation can be reversed as the error signal from EI 5 is increased by a chemical mechanism keeping transmitter flow from decreasing, or even increasing it. This changes only the reference signal; it is, simultaneously, a "short-term memory," in that, so long as the effects of this second chemical reaction endure, the new reference level is maintained. Kandel and Schwartz speculated that short-term memory may shade into long-term memory by way of further chemical reactions involving changed output from certain of the genes in these neurons.

Now look at MN 6 in the circuit diagram; notice that it also meets the requirements for a comparator. It would be a first-order comparator, since it is at the last stage before the gill control muscle. If the diagram is correct, we could expect that the signal coming from EI 5 changes the size of the error signal (simultaneously the motor output) from MN 6 in response to input from SN 24. Thus, EI 5 is a second-order comparator, allowing the reference signal to the first order to be regulated by the interaction between input from the siphon skin and the level of sensory input elsewhere in the system.

We conclude that the circuitry demonstrated above fits the picture of at least two levels of environment control systems. Next, we shall use this interpretation to formulate a conception of what might be the actual mechanism whereby associations are formed in nervous systems.

8.4 Neural Basis of Association: Joining of Systems in the Formation of Higher Orders of Control

The above discussion implicitly dealt with the fundamental issue of associationist theory, the mechanism by which associations are formed. When feedback signals enter the first-order comparator for muscle tension in the gill withdrawal muscle of *Aplysia* and the reference level is not altered, we have what has been called traditionally a "reflex."

However, when feedback signals from sensory receptors in the head and tail —comparable to pain receptors in higher organisms?—are activated and flow through the neural network, they have their greatest effect upon the system controlling the gill muscle, because that is the system which is operating at the time. As we pointed out above, Kandel and Schwartz showed that the means of raising the reference signal to the lower-order system is simultaneously a "short-term memory." The system controlling gill position becomes set to a higher level of input signal for either input, because of the higher setting of the second-order reference signal. The *consequences* of their coincidence in time have remained in the form of an altered chemical reaction.

Some investigators have objected to generalizing about learning from the work on the "withdrawal reflex," claiming that it only demonstrates the conditioning of a reflex, and is not an example of forming an association. We have tried to show in the above discussion that this is a misperception resulting from the way events were labelled in the first place.

If you have an "association" between what you call a perception and what you call a reflex, that is what Pavlov called "conditioning." If you have an "association" between two "perceptions" and don't consider what variable is being controlled at the time, you could call it "association of ideas." The boundaries of what you see as the phenomenon are dictated by the way you label it. Thus, early psychologists noted associations between ideas, or between perceptual categories, such as between the name and color "orange." Since, following Descartes, they thought of the perception as *coming into* the organism, rather than as *controlled by* the organism, they had no reason to think that there was any "doing" going on in the organism, as there is when muscles are contracting and the body moves. True, the "doing" in the case of the association between a sensation of color and an act of naming involves relationship control, which occurs at the level of computing in the brain and does not necessarily result in physical activity. This distinction was perceived previously as fundamental in distinguishing reflexes from associations. Reflexes were thought of as mechanically invariant and always involving some sort of action, such as the knee jerk or secretion of saliva, to mention two of the classic cases upon which traditional theory was built. Once that way of looking at events had been constructed, scholars simply didn't see facts which didn't fit into that frame, as shown next by a discussion of a reflex which failed to occur regularly, as required by traditional theory.

8.5 An Experiment with the Control of Eyeblinking

Some early students of control-theory psychology became interested in repeating a classical laboratory experiment to determine whether they could identify the controlled variable in a simple control system. The classic "eyeblink reflex" was chosen as a good candidate. There is a legend among psychologists that it provides a nice illustration of the conditioning of a reflex. The apparatus is simple. You construct a chin rest in which a subject places his or her head, and next to it you place a pipette which is connected by a tube to a rubber ball or syringe which can be used to send a blast of air onto the side of the subject's eyeball. The "conditioning" involves making a noise, like a click, just before the airblast, and the subject is supposed eventually to blink at the tone without the airblast.

My students set up this experiment with one added feature. They asked the subject to work arithmetic problems which were on the blackboard in the room, telling him or her that they were studying whether the process is affected by the experimental conditions, which they did not clarify. This complication was imposed in hopes of keeping the subject from attending to the airblast as something to be concerned about.

The first subject performed as expected. After a time, he blinked even when the airblast did not come. However, with the second subject, something different happened. He began to blink more frequently, but *randomly* as related to the time of the airblast.

The explanations for these differences draw upon higher levels of control, in which the eyeblink is only the final output. The subject who showed conditioning turned out upon followup questioning to have accepted the task as it was construed for him by the experimenters. He tried to go ahead with working the problems, paying as little attention to outside distractions as possible. The other subject said he quickly noticed the distraction, figured that it played a part in the experiment, and assumed that he was to get the distraction "under control." He did this by resetting his reference signal for more frequent blinking. In other words, the two subjects defined their overall purposes in different ways, resulting in different kinds of overt activity.

The perception of the eyeblink *as the main subject of interest* was from the experimenters' point of view, and it did not take into account the fact that each of these subjects constructed a different control system for the (different) variable defined by *his* purpose. To reach that conclusion, it is necessary to start from a paradigm in which the nervous system is considered to be an interlocked pyramid of nested control systems, rather than a collection of isolated systems which can or cannot become linked by some hypothetical process called "association."

One further observation resulting from the analysis of these experimental results might have considerable consequence for the labelling of such phenomena as various "reflexes." It seemed to us, after going down through the different controlled variables which our subjects were controlling, that it would be appropriate to rename the "eyeblink reflex" a "corneal-lubrication control system," for that is basically what it is.

8.6 Are There Different Kinds of Learning?

There is currently considerable debate about whether there is more than one "kind" of learning: whether "skill" learning is different from "perceptual" or "complex" learning, etc. (See, for example, Fox, 1983.) This confusion resulted in part from the associationist tendency to conceive of every behavior as a thing in itself. Later, when it became apparent that some learned behaviors are parts of other learned behaviors, this tendency already had become entrenched, and it interfered with the idea that all behavior could be interlocked in an overall hierarchy.

Thus, we find Gagne (1970) describing seven categories (or kinds) of learning. They are arranged in terms of increasing complexity—but it is "complexity" as defined by subjective impressions, not in terms of identifying the number of orders of control systems involved. The alternative, Powers' (1973) hierarchical control-system model, suggests that first-order systems are already organized when the animal is born or hatches. They don't have to be organized through experience, and they came to be called "reflexes" because they didn't seem to involve learning. (Unless—to minimize the number of our concepts—we could say figuratively that "life" exhibits learning in the process of evolution whenever a mutation in an existing species results in a new first-order system.)

We saw in the description of gill withdrawal by *Aplysia* that (if the circuitry was pictured completely) the first-order gill position control system was regulated by a second-order system which could tune the sensitivity of the first-order systems under its command. This has been called by different names in psychology: habituation (and its reverse, dishabituation) and adaptation (and its reverse, sensitization). Adaptation is presumed to occur peripherally by way of decreasing rates of firing along sensory nerves, while habituation is more often used to refer to decreased reactions to the same stimulus, thought to be controlled more centrally. In *Aplysia*, however, we have seen that the actual mechanism is that of decreasing amounts of transmitter crossing the first-order synapse. Either term could have been used.

Above the level of first-order systems, or "innate reflexes," we find the phenomena called conditioning, or learning. In these phenomena, larger "chunks" of behavior are examined as units. An innate "reflex"—gill withdrawal or eyeblink—is seen as associated with a more distant sensory receptor than a first-order receptor. It may be more distant in a physical sense, as when electric shock to *Aplysia*'s head or tail sensitizes the first-order system (gill withdrawal). Or it may be more distant in the conceptual sense, as when ringing a bell is followed by salivation by a dog.

We believe we would be justified in saying that there are different kinds of learning only if there were found to be fundamentally different ways of constructing control systems—and we don't expect that to happen. What have been called different types of learning can be put into a much less confusing framework by noting the level, within the organism's hierarchy, of the controlled variable of interest.

In most cases, each level above the first will be found to be constructed as a result of experience. The input of these higher-level systems usually is *not* raw data, such as light waves, sound waves, or the physical conditions which activate touch receptor feedback. Instead, it is more and more complex *integrations*, as argued in Chapter 5. And the output of a higher-order system is the control of reference signals of lower orders.

We already know that some control systems are organized by the growth of dendritic arbors and/or the modification of chemical sequences controlling the firing of neurons. But these differences are not *fundamental* differences in terms of the organization and reorganization of control systems. From now on, we shall translate the facts known about the modification of behavior in terms of controlled perceptual variables, feedback signals, reference signals, error signals, and outputs.

One big difference in describing the facts of prior studies of learning is that we shall not treat each "learning" as an isolated event. Instead of accepting the experimenter's picture of what he or she is interested in, we shall try to get inside the subject's frame of reference to visualize the environment which the subject intends to control. This will inevitably necessitate an analysis of the different orders of control involved in any task.

8.7 A Slight Advance in Control: "Conditioning"

We began this discussion of learning-as-increase-of-control-over-environment with the most elementary example of behavior modification we could find: regulations of the sensitivity of a fixed control system, the "innate reflex." We equated habituation/dishabituation, or adaptation/sensitization, with sensitivity level. Total habituation is synonymous with a reference level of zero. First-order systems, such as the gill withdrawal reflex in *Aplysia*, appear to "fatigue" after a steady flow of input, unless the systems are organized into more complex circuits (by, for example, a shock to the body). The situation prior to "fatigue" is restored by "rest." Kandel and Schwartz (1982) found the chemical basis of "fatigue" and "rest" in the gradual exhaustion and replenishment of transmitter agent at the first-order synapse. They also found that sensitivity could be altered by a second-order input which increases the rate of transmitter production.

This second-order effect, increased sensitivity, occurs with stimulation elsewhere in the organism. If a "noxious" stimulus, such as an electric shock, is administered to the head or tail, the gill withdrawal system shows increased sensitivity (response strength) thereafter. If inputs elsewhere in the system can affect gill withdrawal, then there must be connections by which this influence is mediated. These are, in our terms, the organization of a more complex system.

All of the nerves in a nervous system potentially are connected with each other. An impulse chain started at one or more sensory receptors might flow *throughout* the system, especially if it is very *strong*—a good definition for a "noxious stimulus." Recall Kandel and Schwartz's explanation of the neural/chemical mechanism. A strong shock to the head or tail results in a chemical reaction counteracting the decline of transmitter agents to the motor neuron.[2]

In the above picture, we also have a potential explanation of the simplest kind of memory: the time it takes the chemical modifications to deteriorate is coincident with the duration of the sensitizing effect of the "noxious stimulation." That is just how long the animal "remembers" the previous shock. It shows its "remembering" by displaying increased strength of gill withdrawal for that period of time.

The above description of "associative learning" could just as easily be termed a reorganization of the animal's control systems. We might wonder what the controlled condition might be. That is hard to answer with the data we have available at present. Recall that the controlled condition must be defined with regard to the *subject's* point of view, not the experimenter's. It is not easy to put ourselves in *Aplysia*'s position to visualize which environmental variables its control systems are capable of controlling. We need to add the work of evolutionists and ethologists to that of the neuropsychologists who have provided the data utilized so far. But let us speculate briefly, mostly for practice in reorienting our research thinking in terms of the concept of control. Then we shall show how the tangled web of terms for various "types" of learning, motivation, and perception can be simplified.

What kind of environmental disturbance is a touch, or a jet of water, upon the siphon skin of a mollusc? Since it has some form of mechanoreceptor directly connected with the motor neurons which pull the mantle organs into the respiratory cavity upon stimulation, we reason backward in evolutionary terms. We infer that control of the perception "no foreign object in contact with surfaces surrounding the respiratory organs while exposed" is optimal for survival. It is not difficult to imagine possible illustrations: a large ray swimming near the bottom and stirring up clouds of sand, for example. Next question: how might the evolution of nervous systems up to *this* organism's have developed a pattern in which "noxious stimulation" of any part of the animal could become associated with withdrawal of the respiratory organs?

A nervous system coordinates the actions of the animal as a whole. It is important to keep reminding ourselves of that fact, because the traditional paradigm tends to hide it. The electric shock used as a "stimulus" also introduced tremendous alterations in the electrical fields throughout the organism, setting up a whirlwind of neural activity. The animal is convulsed by the strong shock, according to the researchers. Any number of the "innate reflexes" could be expected to be fired simultaneously in that condition. You have already seen, in the explanation of "sensitization" of the withdrawal reflex, that generalized neural activity throughout the animal results in longer lasting changes in the signal-transmission properties of the whole network.

Thus, you can see that conditioning is not a different phenomenon from sensitization, neurochemically speaking; it is only different in terms of the number of levels of control (neurologically, the number of interneurons) involved. It also involves a longer time scale, but that is also already implied, because conditioning involves repeatedly raising sensitivity (reference level) until longer lasting changes have grown up in the circuitry.

Now, let us take a new look at the history of learning theory, starting with Pavlov and his concept of conditioning. Pavlov (1957) found, as we noted in Chapter 2, that if he rang a bell before feeding the dogs, the animals would soon come to salivate upon the ringing of the bell by itself. At the time he worked (late 19th and early 20th centuries), the facts described by Kandel and Schwartz were not known. He guessed that something of the sort they reported was going on in the brain, but since the methods for studying neural "plasticity," as it is now called, were not developed, he turned instead to elaborating many of the details of "conditioning," as he termed the association between an "innate reflex" and a "neutral stimulus," such as the ringing of the bell.

He found, among other things, that if the bell continued to be rung but no food followed, then the animal finally would stop salivating. He called that "extinction." Note the similarity between that and Kandel and Schwartz's description of "adaptation" in *Aplysia* as the animal gradually ceased withdrawing its gill. It is a good guess that the neurochemical mechanism Kandel and Schwartz discovered could explain, in a general sense, the comparable phenomenon found by Pavlov.

Pavlov varied the details of his experimental setup in many different ways and observed many additional details, for example:

(1) Signals given immediately *after* presenting the food to the animal did not become "conditioned stimuli";

(2) Signals given as long as 5 minutes before the food gradually came to elicit salivation;

(3) Signals, such as a buzzer, presented continuously for a period of time before feeding were followed by salivation after the same time delay;

(4) If the dog is fed at regular intervals, salivation begins to occur at the same intervals;

(5) If several nearby spots on the animal's skin were touched, some followed by feeding and some not, at first all would be followed by salivation, but gradually those never followed by feeding came to show no more salivation.

Pavlov called the last-mentioned observation an example of "inhibition." As he viewed it, the conditioned response was there, but it was inhibited from being put into action. A control-system explanation is that the neural circuits were being reorganized as Pavlov's varying experiments presented the animals with different conditions to be controlled.

Note that there is a constant element in all of Pavlov's results. It is that the animal salivates when perceiving a reliable signal for the arrival of food. Furthermore, the signal is processed in such a way that salivation tends to occur *not* at the moment of the signal, but at the moment of feeding. Obviously, the controlled condition is to have saliva in the mouth upon intake of food.

We shall leave discussion of still more complex types of environmental control for a later chapter on complex learning as higher orders of control. We turn next to perception and motivation as aspects of control, rather than as separate mental processes.

8.8 Learning as Organization of Control Systems for Increasingly Complex Perceptions: Perception Is Not a Separate Process

Scan several inches of this page between the lines, looking for variations in the brightness of the paper. Then scan along a line or two of print looking for variations in blackness of the print. You may think that the material is very uniform. If so, look again. You'll begin to note variations which you didn't see at first. Think about that.

Next, shift your attention to groups of words, but don't read them—simply look for patterns determined by the contrast of print and space. At first, you'll probably find it hard not to read the material, but in time you'll be able to stare at it, and the meanings will begin to go out of focus. You may have found yourself moving the book back and forth in order to vary this experience. If you have some very poor copy handy, such as a typed or dittoed page where the ribbon or ink was getting dim, compare the feeling you get as you look at it. Note the sense of effort in just making out the outlines of letters.

Now shift your attention to the shapes of letters or words. Still refraining from reading the material, notice that if letters are uneven or poorly formed, you'll be making guesses as to some of them. That is, you'll be matching them with mental models of letters and deciding what you're seeing by "goodness of fit." In order to do that, you must have the "shapes" in memory already.

Finally, read the material. Notice that as you begin to take in meaning, the previous kinds of perceptions fade out. If you try to keep several levels going at once, you'll find that you shift back and forth between levels. Do you get a sense of being active as you do that? You aren't simply receiving signals sent by the environment. You're *controlling* your environment. The variable you choose to monitor in each case is brought under control by active effort. Notice that there is usually some time before you get full control at each level. If you wonder how you're able to shift from level to level, remember that before you make an attempt, you first have to set the instructions as a purpose of your own. You don't do the experiment as an automatic reflex. The perception of reality you experience at each level is part of a still larger control system: testing the ideas we were presenting here.

There is one final point to be made. If you were able to control the variable we suggested at each step in the demonstration, it was because you already had a control system for noting degrees of brightness, sensory impressions, shapes of letters, or recognizing meanings of printed words. Suppose you had been asked, as part of the first step, "Note whether the opposite pages in the book are of the same grade of paper." You may have responded, "I'm not a paper grader. How should I know?" You would be saying that you had never organized a control system for performing that task, therefore, you could not perceive the variables which must be perceived to perform it. You may not have a repertoire of the lower-order control systems necessary to carry out such an objective. In that case, it would be necessary first to develop control over lower-order perceptions, as when a music teacher will not accept someone for voice lessons until he or she learns to read music. Conversely, you may have the required lower-order systems, but under the control of some other higher-order system, as when an

American driver travels to England and must get his or her systems for keeping a car on the road under the command of a new principle, "keep to the left side."

Implicit in the above point is a general group of questions which have plagued learning psychologists for a long time. When does previous learning help, and when does it hinder new learning? Or, in somewhat more technical language, is there "transfer of training?" Some research has suggested that there is. Other research has failed to find it. Still other research, such as that on rote memory, has found both "retroactive interference" and "proactive interference." In everyday terms, "retroactive interference" means that you can expect poorer performance in recalling material learned previously if you follow it by learning other material, and "proactive interference" means that you do less well in memorizing rote material if you have just memorized some similar material. These findings help (a little) to answer a more general question: When is a person helped by what he or she already knows in learning something new, and when might what he or she already knows make new learning more difficult?

Questions such as the above are well on their way to becoming outdated as we begin to reframe research on how people develop increased control of specified controlled variables. The kind of research done by Jean Piaget, showing how various abilities are gained step by step, appeals to us as leading to more reliable generalizations than most traditional learning research, which attempted to study each phenomenon of interest as if there were no previous organization in the brain.

Notes

1. Kandel and Schwartz (1982) worked out further details of the biochemistry of the mechanism, showing that cells of the type marked FI in the diagram release serotonin onto the terminals of the sensory axons innervating the motor neurons. When that happens, cyclic AMP in the terminals produces an increase in the amount of transmitter sent across the synapse to the motor neurons.

2. Specifically, firing of interneurons between the affected receptors and the system controlling gill withdrawal; that, in turn, results in serotonin release at the first-order sensory endings, which, in turn, results in cyclic-AMP enhancement of transmitter release at the first-order synapse, strengthening the feedback to the first-order comparator.

Chapter 9

Developmental Psychology: Developmental Stages as Successive Reorganizations of the Hierarchy

9.1 Introduction

The field of developmental psychology grew partly in reaction to the fact that learning theorists in traditional psychology took almost no account of the influence of previous experience upon learning during childhood. Based as it was in the Pavlovian conditioning paradigm, learning theory was filled with research studies about variables relating to "reinforcement schedules," motive strengths and the like—all treating each instance of learning as if it began on a blank slate, independent of what the individual could and could not do before the current learning episode began. Educators and clinicians working with children found much lacking in this approach of learning theory. They knew that education is in many ways a *sequential* process, in which new tasks are begun upon the level of mastery acquired in previous tasks. Hence, they became interested in the psychoanalytic concept of "stages" of development, as formulated by Freud and greatly elaborated by Erik Erikson (1950).

9.1.1 Freud

Sigmund Freud (1905/1953) postulated three stages through which he claimed all children progress during normal development (and a fourth, inserted between childhood and adult phases of the third), as discussed in Chapter 11, below. His basic theory was built upon a model of *energy investment*, rather than being directly concerned with learning, but it contained a clear implication that the child acquires different abilities during the oral, anal, genital, and latent stages or developmental periods. During the oral stage, the child's attention and awareness is focused mainly on all the activities surrounding intake of nourishment—the mouth zone—and the major energy of growth is invested there. Then, sometime around the age of 2, the major focus of attention shifts to matters surrounding excretory control, in potty training. Between 3 and 5 it shifts again, to interest in genital development. Finally, in the elementary school years, in what Freud called the "latent period" in genital maturation, it shifts away from the individual's body to the acquisition of skills for dealing with the outside world.

9.1.2 Erikson

Erik Erikson (1950), a psychoanalyst of children, greatly expanded Freud's concept of developmental stages, defining eight from infancy to adulthood. Erikson's theory also introduced the concept of the developmental "crisis," which he saw as occurring in the transition between each developmental stage and the next, an idea with features in common with Powers' concept of reorganization.

Another interesting feature of Erikson's scheme is the notion that each stage is characterized by tension between a healthy and an unhealthy polarity. The developing individual resolves the transitional crisis between stages upon some particular position within the continuum, depending on his or her experiences up to that time. Thus, Erikson's first stage, "Trust versus Mistrust," incorporates the idea that the infant concludes this stage by forming a basic attitude about the benevolence of the environment according to his or her experience of being cared for in it.

Erikson defined his second stage as "Autonomy versus Shame and Doubt." Paralleling Freud's hypothesis that toilet training provides the growing child's first clear experience of voluntary control over his own bodily functioning, Erikson again described the polarity between the healthy outcome, autonomy, and that of the child whose development has been disturbed, who feels shame at failure to control his or her excretory functions at will. The third stage, "Initiative versus Guilt," develops on the foundation established by the resolution of the previous stage, and occurs in the immediate preschool years, when the child is learning to venture out into the world on his or her own. Guilt is the feeling of having done something wrong when the child's developing initiative meets disapproval from his or her caregivers.

The fourth stage, "Industry versus Inferiority," occupies the elementary school years, and is taken up with development of the basic skills needed in a technically complex civilization, such as reading, following directions, mathematical skills, visual-motor coordination, and the like. The next stage, "Identity versus Role Diffusion," is played out in adolescence, and involves experimenting with various social and work roles leading up to self-definition at the threshold of adulthood. And once the identity (or in control-theory terms, the self system) comes into existence, the next task is that of forming an intimate relationship —"Intimacy versus Isolation"—for the adult functions of family and home life. Erikson called the stage of mature adulthood "Generativity versus Stagnation," because that is the time when the mature individual is most likely to make his or her greatest contributions to society, and to starting offspring on a constructive path in life. And finally, the last stage, "Ego Integrity versus Despair," is that when the aging person either has a meaningful life upon which to look back, or has a sense of despair over having wasted the opportunity.

9.1.3 Piaget

Another prominent developmental theorist was Jean Piaget (1926, 1928, 1930, 1932), who described many separate sequences of increasing complexity of individual cognitive, or intellectual, abilities. He aggregated the various sequences of skill mastery which he described into stages, according to the different underlying principles which he felt were embodied in the behavioral sequences he observed. The first he called the "sensori-motor stage," in which the child develops various bodily controls. The next is the "pre-operational stage," in which the child turns attention to the surrounding environment. The next is the "concrete operation stage," in which the child begins to acquire the mechanical skills which give control over the physical environment, and finally there is the "formal operations stage," in which the individual learns to conceptualize and perform abstract computations, to function in the technical and social environment.

Piaget also proposed that there is an oscillating development between "accomodation" and "assimilation," in which the child first acquires a new way of perceiving some aspect of the environment, and then extends the newly acquired "schema" to enable further control. These concepts resemble the phenomena of reorganization and consolidation of the control-theory view presented above in Chapters 7 and 8.

Each of the developmental theories noted above are *qualitative* and *descriptive*, and not readily harmonized with what is being learned currently in the biology of neural development. They are full of interesting details and are recommended for further study by the interested student; however, we now provide a more quantifiable, control-theory analysis of the development of control over increasingly complex perceptual variables. Our (F.X. Plooij and H. van de Rijt-Plooij) work on behavioral development in human and chimpanzee infants illustrates an application of Powers' hierarchical, negative-feedback control theory, showing its utility in organizing and making sense of the data, and illuminating the relationship between development of the nervous system and control over increasingly complex environmental variables.

9.2 Development from the Control-Theory Perspective[1]

It is probably no accident that the start of control systems theory and ethology occurred in the same decade, the 1930s. Along with Lorenz and Tinbergen (1938; Lorenz, 1939; Tinbergen, 1951), who were working in the mid-30s to found ethology, Von Uexküll (1933) and Kortlandt (1940a and b, 1955) were combining control concepts and ethology. Since then, there have been several generations of ethological researchers dealing with hierarchical levels of organization underlying overt behavior, seeing the hierarchy consisting of negative-feedback control systems. It was from this tradition that we started to study infant development and became fascinated by the explanatory power of Powers' model.

Two studies were done on chimpanzee mother-infant pairs in the Gombe National Park, Tanzania, East Africa. In the first study—of the behavioral development of free-living chimpanzee babies and infants (Plooij, 1980, 1984, 1987)—we collected quantitative observations of motor development in its social-ecological context. Using ethological methods, we described the induction and facilitation of motor acts in the repertoire of individuals who had been observed for periods of months, or even years, and analyzed the observations of overt behavior in the case-study material for the ontogenetic development of its underlying organization. This approach was based on the early ethologists' demonstration that entire sequences of behavior can be described, and thereby subjected to analysis. Behavior was viewed as made up of "elements" or discrete motor-patterns, which integrate into functional sequences. These discrete patterns of behavior were used in the search for the existence of behavior-control systems, which were, in turn, considered to control functionally related activities in adults.

These fundamentals of the ethological approach were to cause problems in the search for control systems underlying very early chimpanzee behavior. It was impossible to find discrete motor patterns under the age of 5 months. This finding was paralleled by Condon's (1979) frame-by-frame analyses of body motion in human neonates. A similar conclusion had been reached by Fentress (1976,

1983) for non-primate mammals. He found that only after the age of 10 days could he easily identify stroke types in the grooming of mice; they only became predictable and "stereotyped" after this age, which is comparable to approximately 5 months for chimpanzees.

Another means of looking for the existence of control systems in early behavior prior to the age at which discrete patterns emerge is by exploring what have been called "consummatory stimuli" in the ethological literature. For these phenomena, it has been observed that feedback through proprioception and other sensory modalities plays an important role in primates, mice, and some bird species. The critical feature is feedback of deviation from set values: as soon as the perceived stimuli conform to the set values, all activity related to them stops.

These consummatory stimuli can be used to aid in finding the control systems underlying behavior. Let us describe what such stimuli look like, using the thermal and tactile perceptions which are controlled in neonatal behavior. For instance, a specific optimal temperature appears to function as such a consummatory stimulus in neonatal rooting for the nipple. Rooting appears to be guided by a temperature gradient—the nipple having the highest temperature. The neonate actively searches for the highest point in the gradient, then stops the rooting activity. Teitelbaum, Schaller, and Whishaw (1983) showed that other elementary vestibular, kinesthetic, and gastric stimuli are also important in the control of normal behavior in human infants. Chimpanzee babies of 2 months and older, however, show overt behavior which can no longer be directed at obtaining such simple consummatory stimuli. For instance, finding a nipple through rooting guided by a temperature gradient has disappeared by this age. From this age onwards, babies show the so-called "directed head-turning response," and go straight to the nipple, if they have been continuously on the body of the mother.

Thus, the question arose: what new consummatory stimuli start to become prominent in babies of 2 months and older? But this question was not readily answerable. These stimuli are, so to speak, hidden. The behavior seems chaotic to the observer as long as one does not know what is being controlled. As soon as one *does* know, the underlying order becomes apparent. It was at this point that Powers' method of looking for controlled perceptions proved useful.

We used three procedures for such investigations. The first was to study reactions to disturbances. An organism can be said to control a variable with respect to a reference value if every disturbance tending to cause a deviation from that value is met with behavior opposing the disturbance. In field studies, it is not possible to apply disturbances and look for countering behavior, but it *is* possible to look for naturally occurring disturbances and observe behavior following them. Everyday life is full of such "natural experiments."

A second way to decide what type of perception is under control concerns the speed of control systems. First-order control systems are very fast—about 0.1 second or less. The higher the order of control, the slower the reaction time. This allows all orders of control to work simultaneously. Furthermore, control systems oscillate when they become unstable. Since the higher the order of control, the slower the oscillation, the frequency of oscillation also provides information about the order of control involved. A few examples will clarify this. "Clonus" oscillations result from unstable first-order control systems when muscles exert excessive effort. They oscillate at roughly 10 cycles per second. Several types of "tremors," such as in Parkinsonism, oscillate at approximately 3 cycles per second, evidencing second-order instability. Finally, over-correction, such as over- or undershooting the target while reaching out for something, results from third-order instability.

A third way to decide what type of perception is controlled concerns the degree of variability. The disappearance of rigidity in the control of a certain variable indicates that the order of control has changed from being the highest level to being the next-to-highest level. This follows logically from the hypothetical construct: as long as a certain control system is the highest in the hierarchy, there are no higher-order systems superimposed on it to adjust its reference level, and therefore variation is absent. As soon as a higher-order system becomes operative, the reference signal is adjustable, and variability in behavior is then observable. This was found true by Kortlandt (1955) in the behavior of cormorants, a species of waterfowl. His conclusion was that "[this] zone of variability in behavior ascends in the same degree as does the progress in maturation."

9.3 Types of Perception and Learning

Now we return to the question of what type of perception is controlled at what age. We detected five clusters of changes in the behavior and perception of chimpanzee babies and infants during the first year of life (Plooij, 1980, 1984). Each of these clusters tends to center around a certain age, and can be understood in terms of a new type of control system being superimposed onto the already existing hierarchy of control systems. The following statements summarize these findings.

(1) The chimpanzee neonate has a nervous system with no more than two orders of control.

What evidence supports this statement? First of all, the neonatal perception is still close to a total unity. This is indicated by the fact that a very wide range of stimuli in several sense modalities can elicit the vocalizations "staccato" and "uh-grunt." These vocalizations are produced in relation to any disturbance, any sudden change in intensity, regardless of the nature of the physical variable in which the change in intensity occurs (for instance, a sudden change in light intensity by a cloud moving in front of the sun and the shadow moving across the baby, or a sudden sound, such as the creaking of a tree branch, sudden thunder, or breaking wind by the mother). This intensity-control way of reacting to all kinds of disturbances indicates that higher than second-order control systems are not yet active.

Second-order systems control sensations, and the behaviour of chimpanzee neonates is very much ruled by sensations. For instance, thermoregulation plays a part in "comfort-contact search," and in rooting towards a nipple. That higher than second-order systems are not yet active can be concluded by employing two of the three strategies described above. Lack of variability in the comfort-contact search is the first indication that no more than two orders of control are functional. As long as the temperature is deviant from the optimal state, the contact-comfort search proceeds; as soon as the optimal temperature is obtained, the search stops. This implies that there is *one* fixed target value or reference value for this system. The speed with which the neonate's head oscillates from one side to the other during rooting provides the second indication that no more than two orders of control are operating. This occurs with a frequency of 2-3 cycles per second (Prechtl, 1958). If this frequency is compared with the frequency of a clonus or a tremor, rooting may be considered to result from an unstable second-order control system.

(2) Around the age of 2 months, a cluster of changes is observed which leads to the conclusion that a third order of control has become operative.

This conclusion is based on the following evidence. The speed with which the head oscillates during rooting has changed. Rooting has been replaced by the head-turning response. One turn of the head from one side to the other lasts 2 seconds instead of 1/3 to 1/2 second. The oscillation has become slower, thus a higher order must have become operative. The chimpanzee baby of 2 months and older does not whimper anymore when ventro-ventral contact is broken. Thus, variability has appeared in the comfort-contact search. This variability in second-order control indicates that a higher-order control system must have become functional, allowing the second-order reference signal to vary.

Next, a shift occurs in vocalization, from staccato-production in response to changes in intensity, to selective responsiveness to more "specific" stimulation. The shift is quite dramatic and steep after 2 months. The main form of such "specific" stimulation is the sight or calls of other chimpanzees. This implies the ability to perceive visual and acoustic patterns, and that is, among other things, what the control of configurations is about. In addition, the infant begins to show a sudden interest in the face of the mother and visual patterns in general, indicating a new ability to differentiate visual configurations. A sudden preoccupation with bodily configurations is accompanied by starting to make all kinds of faces, moving mouth parts, newly found control over various body positions, and moving the hands to and fro in front of the eyes.

Again, the quality of the behavior gives us an extra clue as to what order of control has become operative after 2 months. At the age of 8 weeks, a baby was observed to grasp something for the first time. This occurred with an enormous overshoot, also called "purpose-tremor." Such an overcorrection is typical for a third-order control system. The fact that fourth-order control is not yet active may be deduced from the quality of another behavior: at the age of 7 weeks, a baby was observed to scratch itself for the first time, but in a very "wooden" way; the whole hand was alternately flexing and stretching. The scratching was directed only at the body spot where the hand happened to be, even when an itch was in a totally different spot. This shows that the 2-month-old is not yet able to bring its hand to a certain body location, and that it fails to make smooth transitions between one arm-hand configuration and another. Thus, fourth-order control still appears to be absent.

The cluster of changes around 2 months also has consequences in the social realm. The mothers stop carrying and supporting their babies. This is understandable if one realizes that the baby is now able to perceive and control bodily configurations, including the ability to support its own body weight by maintaining a clinging position while hanging under the belly of the mother. This is something the baby was not able to do before the age of 2 months. We observed a natural experiment which cruelly proved the latter statement. An adult female chimpanzee lost the use of one arm after an epidemic disease. She had raised two infants successfully before. Two more infants were born after her arm was paralyzed, and both died in the first few months because the mother was not able to support them properly: they frequently fell down, off the body of the mother. When she was in a tree, this was lethal.

Having illustrated our method of reasoning with this first cluster of changes around the age of 2 months, we shall proceed faster and more sketchily through the remaining clusters of changes.

(3) Fourth-order control—transitions—emerges between 3 and 4 months.

All movements become much smoother. The purpose tremor and other jerky movements are not observed any more. The evidence for the emergence of this order needs to be pursued further.

(4) Fifth-order control—event-sequences[2]—emerges near the age of 5 months.

For the first time in the development of the babies, it is easy to observe discrete motor-patterns such as walking quadrupedally and climbing. Event-sequences can occur in all modalities. As for proprioception, sequences of transitions in posture and discrete motor patterns (such as the event of picking a fruit) are now observable.

In the social realm, the first severe conflicts and forms of weaning are observed between mother and infant. Access to the belly and the nipple is restricted for the first time in the baby's life. The babies do not give in easily; sometimes the mothers use force to pull their baby off the belly or the nipple, and push them onto their backs. For the first time in their lives, the babies are mainly responsible for maintaining ventro-ventral contact.

(5) Between 7 and 9 months, a large cluster of changes can be observed, suggesting yet another order of control emerging—that of controlling relationships.

During this time, the number of discrete motor-patterns increases remarkably. This suggests that the fifth-order control of short, familiar event-sequences has come under the control of systems one step higher in the hierarchy, causing a great deal of variability at this level. The infant starts placing objects against certain body spots frequently: object on top of head, object into neck pocket, object against belly, etc. These behaviors could not be performed without the ability to perceive and control the relationship between object and location on the body.

In month 8, there is a rather abrupt change in the way the infant makes excursions away from and back to the mother. These excursions become more frequent, but shorter in duration, and the infant stays closer to the mother than at an earlier age. The infant shows concern over the distance to its mother by whimpering when this distance is increased beyond a certain amount. (Distance is also a relationship-control variable.) Six anomalous motor-patterns were observed for the first time, expressing conflict between tendencies to approach and withdraw. The social gesture of "begging" also appeared at this time, and then socio-sexual behaviors of presenting, mounting, and thrusting at around 9 months.

(6) Finally, toward the end of the first year, the beginning of the ability to control programs can be seen.

These are control sequences of relationships between events and lower-order perceptions, brought about one after the other. Examples among humans include eating soup with a spoon, vacuum cleaning, and the like. Among chimpanzees are the first imperfect forms of termite-fishing, nestbuilding, food gathering, and other functional behavior sequences—the idea of "syntax" of behavior, according to Lashley (1951).

In the social realm, sixth- through ninth-order variables are involved in the abrupt shift from ventro-ventral contact with the mother around 7 months, changing to looser contact, with a further drop to general body contact about 50% of the time between the 11th and 12th months, with more staying out of contact, but within arm's reach, after that.

(7) Possible emergence of tenth-order control—principles—around 18 months.

To support this statement, we have data only on some aspects of the mother-infant interaction. What we observed was a second drop in the amount of time spent in body contact, occurring around 17 to 18 months. Body contact dropped to about 30% of the time, and remained at this level thereafter. This drop also was marked by a shift from staying mainly within arm's reach to staying at an average distance of about 1.5 to 5 meters from the mother.

Not only our field data, but also many other neurophysiological and neuroethological data are neatly integrated within the framework of Powers' control hierarchy model. For example, Cools (1985), in a review article on this subject, noted that various authors have observed that recovery from brain manipulation proceeds through the same sequence of types of perception, becoming operative within the span of about half an hour, as if a film of development were speeded up.

9.4 Canalization, New Types of Learning, Regression, Mother-Infant Conflict, and Vulnerable Periods

Our second study—on the growth of independence of the infant chimpanzees (Van de Rijt-Plooij and Plooij, 1987)—revealed that individuation proceeds jumpwise, rather than gradually. The jumps toward greater independence are preceded by mother-infant conflict. This conflict is often preceded by regression in the infant. These regression-conflict episodes coincide with the same ages at which new controlled perceptions were seen to emerge. (Compare McGraw, 1974; Werner, 1948, 1957; Kortlandt, 1955; Peterfreund, 1971; Mounoud, 1976.) For instance, the ability to perceive and control configurations, as noted at 2 months, is not simply control of visual configurations. It involves control of invariances in all of the perceptual modalities. In proprioception, it means maintenance of body posture, and, in the control of proprioceptive configurations, it takes the form of a new ability of the infant to attach itself and cling to the mother without help. Thereafter, the mother abruptly stops supporting and carrying the infant.

At the age of 4 to 5 months, with the advent of the ability to control event-sequences such as walking, we observed that the mothers became aggressive with the infants when the infants attempted to attach ventrally or approach the nipple. Now the infant was capable of climbing onto her back and climbing up and picking food for itself. At the age of 7 months, with onset of the ability to control relationships, we observed infants for the first time showing concern over maintaining the distance between self and mother. At approximately 10 to 11 months, with the beginning of the ability to perceive program-level variables in self and mother, mother-infant conflict appeared limited to that level. For example, the mother would push the infant away while fishing for termites. The infant then would appear to perceive her in the midst of a program, and relinquish attempts to restore contact. Or mothers sometimes would start travelling without first signalling it to the infants, and the infants apparently would recognize the transition from one program to another and return to their mothers.

Additional evidence of the infant's ability to control program-level perceptions at this age is provided by a description of human infants of 11 to 12 months by Bowlby (1969). He notes that the child becomes able to anticipate the mother's imminent departure at this age.

The foregoing has presented a picture of infant development as a series of "quantum jumps" interspersed with periods of stability. The effects of a developmental advance disrupt the existing homeostasis. For example, when a chimpanzee baby acquires the ability to climb, and thus to get perspectives which it has not had previously, not all of the consequences are pleasurable; it means entrance into an alien world in which new perceptual variables are not yet under control, and old, familiar ones are often lacking or distorted. This is probably the fundamental condition called "anxiety" later on. The infant's ability to operate in this alien environment suffers a deficit in efficiency, and regression to the simpler, familiar, previous control level offers one way to restore homeostasis and relieve stress. Peterfreund (1971) noted the need at this point for collaboration from the mother. Thus, the mother and infant could be viewed as a self-regulating homeostatic system in which the mother's role is to aid in relieving stress, while at the same time not indulging the infant's regression to the point that the oncoming reorganization does not occur. If she knows the learning capacity of her child well, one can hypothesize that the conflict following regression consists of her resistance to it, modulated by facilitating the progress into reorganization.

We have observed mothers forcefully teaching infants to use newly emerged abilities they might otherwise not have employed. The mothers did not reject the infant as a whole, but certain aspects of its behavior. The mother contributes by demanding the action which requires the infant to reorganize. As the infant achieves the next stage, the conflict disappears.

In contrast, the infant may never develop certain skills if it does not get the opportunity, or is not forced. For instance, chimpanzee babies in captivity show a delay of many months in taking their first steps when not forced to do so, depending on the type of caretaking they receive.

In this scenario of developmental advance, regression, conflict, and reorganization, the behavior of the baby is the main focus of attention. However, a more appropriate focus might be the interaction of parenting behavior and developing infant behavior. From an evolutionary perspective, one might say that the nature of infancy (in mammals) and parental care resulted from a process of co-evolution. Especially in humans, infancy and parental care are long lasting and intensive, and constitute a drain on the mother's resources. Consequently, parental care is withdrawn, step by step, as soon as each type of transaction is no longer needed. The timing of each step of withdrawal is determined by the canalized infant development. When the mother perceives each new type of control level (as described above), she recognizes the potential for increased educability, and withdraws some privileges, thus forcing the baby to use its new ability. The infant does not give in readily, and conflict ensues, with resultant stress. Learning occurs as long as the stress is not too great; otherwise it becomes pathogenic. Increased knowledge of what can and cannot be expected from the developing infant at each level will aid in the avoidance of pathological developments.

Observations on chimpanzee babies who developed illnesses have shown a connection between maternal incompetence, stress, and breakdown during periods of vulnerability (Van de Rijt-Plooij and Plooij, 1988). One male chimpanzee baby experienced more maternal insensitivity from birth onwards when compared with three others being raised at the same time. Though he showed the jumps in independence at the same ages as the others, his mother also forced him to do things beyond his abilities. Only when he panicked did she relent. Furthermore, she was rougher and less patient than were the other mothers. She paid less attention to him, forcing him to devote more energy to keeping track of her. He appeared ill between 12 and 14 months, after performing an exceptionally high proportion of the work in maintaining contact from the 9th month on. Likewise, a female chimpanzee infant appeared ill in the 20th month, following a

3-month period of disproportionately greater contribution to maintaining arm's length contact with her mother than provided by infants who did not develop illnesses.

The human family represents a further adaptation of extended investment in the offspring, with the channeling of male parental energy into the rearing of the young, making possible the raising of dependent juveniles along with the nursing of an infant (Lancaster and Lancaster, 1983, 1987).

Other aspects of co-evolution are seen in the intertwining of instinct and learning in development. As Gould and Marler (1987) put it, instinct and learning are partners: "[an] animal is innately equipped to recognize when it should learn, what cues it should attend to, how to store the new information and how to refer to it in the future." Evidence for indwelling of such instinctual control in learning appears in the similarities in sensori-motor development, apart from some differences in timing, which are found in chimpanzee, gorilla, and human infants.

Examples in the literature of predispositions for specific learnings during human infancy are the following: the ability of neonates to recognize the more than 24 consonant sounds characteristic of human speech (Eimas, 1985); the syntactic-lexical and temporal-melodic features of fathers' and mothers' speech to their 3-month-old infants, termed age-specific, dyadic parental (training) adjustments (Papousek, Papousek & Haekel, 1987); the babbling which infants all over the world begin at the same age (Van der Stelt and Koopmans-van Beinum, 1986), eventuating in the resolution upon consonants of their own language through learning; and, in general, Scarr-Salapatek's (1976) conclusion that all of the sensori-motor skills described by Piaget are found in all non-defective human infants reared in natural environments. Such learning predispositions are not all present from birth, however. They emerge at specific ages. Among the examples noted above, consonant recognition emerges shortly after birth, hand gazing occurs around 3 months, and babbling begins between weeks 18 and 23. Thelen (1979) found that the stereotypy groups "fingers" and "legs" showed a mean onset at 8.7 weeks and 9.4 weeks, respectively. Van Wulfften Palthe and Hopkins (1984) noted that at around 9 weeks, babies become able to maintain postural control, sustain looking towards the mother, and produce "pleasure" vocalizations. After 2 months, human babies can focus on qualitatively distinct features, figures, or patterns (Salapatek, 1975, p. 194). Other invariances are described in reviews by Emde and Gaensbauer (1981); McCall, Eichorn, and Hogarty (1977); and Trevarthen and Hubley (1978). Trevarthen and Marwick (1986) reported an observation congenial to the co-evolutionary picture of parenting and development. They noted that, among five mothers they observed, there was a sharp rise in directives and commands about actions as the infants became more cooperative around 9 to 10 months.

Four major biobehavioral spurts or shifts are agreed upon in the literature. Such discontinuities are defined as qualitative changes which are both large and rapid (Fischer, Pipp, and Bullock, 1984). Several investigators have posited shifts around 2, 7, 12, and 18 to 21 months (Bates, 1976; Bloom, 1973; Emde and Gaensbauer, 1981; Fischer, 1980, 1987; Kagan, 1971; Konner, 1976; Lamborn and Fischer, 1988; McCall, et al., 1977; Plooij and Van de Rijt-Plooij, 1989a; Siegler, 1989; Trevarthen, 1988; Volterra, 1987; Zelazzo and Leonard, 1983). This is not to say that there are no more shifts. Infant growth also occurs unevenly, in spurts, as measured by length and head circumference. Both spurts tend to occur together. Thus, growth spurts are significant biological phenomena. These growth spurts do not go together, however, with the major biobehavioral shifts: there are many more growth spurts (Lampl and Emde, 1983).

The question which remains is whether there is a general inclination for maturational spurts to affect all domains, or whether growth spurts and biobehavioral shifts are based on fundamentally different processes. For a start, this boils down to the question of whether there are more biobehavioral shifts than the four recognized so far. There is already evidence for at least one more biobehavioral shift around 4.5 to 5 months (Plooij and Van de Rijt-Plooij, 1989a). This fits with the observations of Mahler, et al. (1975, p. 52) describing the beginning of the first subphase of separation-individuation, namely differentiation, between 4 and 5 months. This extra shift around 4.5 months is also supported by five different groups of investigators, who report no less than five stages of vocalization development during the first year alone (Proctor, in press).

In a study on human mother-infant pairs (0-20 months of age), we focused on the regression part of the story, and found 10 periods of disorganization (Van de Rijt-Plooij and Plooij, 1990). Furthermore, we counted 140 cases of childhood diseases among 98 infants later brought to the special school attached to the Pedological Institute of the City of Amsterdam, and observed that the onsets of disease were not uniformly spaced over time (Plooij and Van de Rijt-Plooij, 1989a). Replicating these retrospective data in a prospective, longitudinal study revealed that the disease peaks shortly followed the regression periods.

9.6 Conclusion

The hierarchy of controlled variables developing step-by-step during growth from birth to maturity, plus the concepts of instinctual predisposition, co-evolution of parenting, disruption of homeostasis, regression, conflict, and reorganization [compare Erikson's developmental crises described in section 9.1 (RJR)] provide us with powerful tools for investigating the dynamic whole, of which these are aspects. Such research should increase our knowledge of the process of development, and it holds out the promise of a better understanding of the deficiencies and excesses of caretaking which may be involved in turning the delicate balance of biological and psychological factors in either healthy or pathological directions.

Notes

1. Portions adapted from Plooij (1987), Plooij and Van de Rijt-Plooij (1989a), and Plooij and Van de Rijt-Plooij (1989b).

2. In his 1973 version, Powers termed the perceptual variables controlled by fifth-order systems "sequences." In the present version, the controlled perception of a fifth-order system is termed an "event," for reasons indicated in the 1973 book (p. 140): "One word for such elementary sequences is *event*... because... when an event begins, a person gets an impression [of a single experience in progress] and this impression remains throughout the event."

Foreword to Part 4

Three of the next four chapters are identified with the familiar subjects of traditional psychology: perception, personality, and social psychology. We shall examine typical studies from these subdisciplines and analyze them in terms of the control-theory model, after describing as concretely as possible the tasks which subjects were performing. You will see that the traditional boundaries of psychological specialties are difficult to maintain when examined within the control-theory framework. It is possible that a future generation of researchers will tease out particular details of the different levels of controlled variables in the hierarchy—a different kind of specialization.

Chapter 12 analyzes several studies from the overlapping traditional areas of learning, perception, and social psychology. The control-theory perspective on these studies should further enhance viewing human behavior from the standpoint of the individual *outward toward the environment*, as opposed to the traditional view of the person as object of environmental forces, rather than as controller of them.

Part 4

Reanalysis of Traditional Topics

Chapter 10

Perception: Input of Control Function

10.1 Introduction

In traditional psychology, perception has been viewed as an independent function within the organism. It has been distinguished from *sensation*, the process by which an organism takes in "raw" information about its environment. Perception has been regarded as the process by which sensory data are converted into the more complex patterns which most behavior has been thought to involve.

The traditional approach was to separate behavior into three independent processes: perception, motivation, and action. Perception was not organized in a hierarchy of increasingly complex variables, as in the control-system scheme of Part 2. In this chapter, we compare the traditional view of perception, and some of the research studies derived from it, with the control-theory view. In the control-theory view, the *perceptual signal* is the input aspect of the control process at each level in the hierarchy; it is *not* independent of what the organism is doing. Perception and motivation, as aspects of the individual's control over his or her environment, are separate processes only in a very artificial sense.

We shall approach the subject matter according to the traditional organization in the literature, examining it from a control-theory point of view. Researchers using the traditional approach have gathered many interesting observations, and they have helped to define many of the issues concerning how physical variables in the environment become information for the person. We shall take a look at some of their findings, accepting the "phenomena" as defined by the psychologists specializing in the traditional field of perception, keeping in mind that in the traditional approach, perception has been considered to happen *before* the organism acts, rather than as an inseparable *part* of action.

Consider the research studies on the following topics, and look particularly for what the subjects in each experiment had to *do* as the experimenter gathered his or her data. This will provide a bridge for moving from the traditional to the control-theory orientation in understanding the subjects' actions in the experiments described.

10.2 Can Perception Exist without Control?

10.2.1 Two-Point Sensitivity

McConnell (1982) and McConnell, Cutler, and McNeil (1958) report the 19th century discovery of the physiologist Suslowa (1863) that when he touched two points very close together on a person's skin, the individual could not always say for sure whether one point or two points had been touched. (How far apart the points must be in order to be distinguished as separate points varies for different areas on the skin.) However, when Suslowa urged his subjects to *guess*, they were, on the average, significantly more accurate than they should have been by chance. This discovery became the basis for distinguishing *physiological threshold* from *perceptual threshold*.

Suslowa concluded that a person can "react" to a "stimulus" without being able to perceive it; he defined that as being over the physiological threshold. When the points touched are far enough apart so that the subject is clearly aware of the number of points, he defined that as over the perceptual threshold. Of course, these definitions derived from the assumption that perception begins *outside* a person—as a "stimulus" which one might sometimes "get" without "responding" to it, as when you notice what a person or scene looks like without doing anything about it.

The definitions of the two thresholds were made necessary by Suslowa's observations. Otherwise, psychologists of the time would have had to abandon the view that behavior consists of responses caused by stimuli, since Suslowa's results indicate that behavior between the physiological and perceptual thresholds consists of responses caused by stimuli only part of the time. These definitions eventually became muddied by the more recent concept of "perception without awareness." This new concept has been a basis for some interesting observations, despite its being logically inconsistent with the definitions leading up to it.

10.2.2 Perception without Awareness

The following results came from studies resting on the assumption that people sometimes receive signals which are too weak for them to be aware of receiving, comparable to Suslowa's reports of reactions over the physiological threshold, but under the perceptual threshold. McCleary and Lazarus (1949) reported that subjects tended to show increased psychogalvanic indications (that is, greater electrical conductivity of the skin, considered to be a sign of anxiety) when words, projected on a screen and paired with electric shocks, were projected again, but too fast for the words to be recognized.

In another study, Miller (1940), pretending to explore extrasensory perception, projected pictures of geometrical forms very faintly onto the back of a two-way mirror, and found that many of his subjects seemed to get information about the forms, even though they reported "seeing" only what the mirror reflected.

Still another example of "perception without awareness" was given by Byrne (1959), who viewed his results as subliminal responses to ideas about food. His study is an example of the type of experiment which has been used by the advertising industry as a basis for "subliminal marketing." It rests upon a controversial method in which shoppers allegedly are given suggestions to buy various things without being aware of receiving the suggestions. (The suggestions are made by way of weak sound or visual messages hidden in music or video broadcasts.) What Byrne actually reported was that a majority of his subjects, exposed to the 1/200th-second message "beef" flashed on the screen while viewing a movie, gave higher ratings to a question about how hungry they were than did subjects who did not get this signal. That is, the average rating for the group of exposed subjects was higher than the average rating for members of the non-exposed group. Other measures showed no difference between the groups. For example, there was no difference in preference for beef sandwiches over other foods.

These experiments have two features in common. For one thing, they do seem —at first glance—to warrant the conclusion that sensory input can be received even though it is so faint that the individual seems unaware of receiving it. But that conclusion turns out to rest upon the traditional way of formulating and interpreting the experiments. It involves the hidden assumption that behavior is a response to a signal from the environment, and hence that "perception" can be examined meaningfully as a thing in itself, without regard to what task a subject is actually engaged in. These data form a different picture when we work from the control-theory assumption that behavior is always controlling one's perceptions (and one's control hierarchy is always controlling all the variables it can). This leads us to separate two ideas which tend to be mixed together in the traditional literature: that a person could "respond" to a signal without knowing there was a signal, and that one could "perceive" something too faint to be aware of it.

Let us begin with Suslowa's (1863) experiment. Some of his subjects seemed to guess correctly the number of points touched on their skin, even when they didn't "know" the true answer. What perception might a person be controlling as a subject in this experiment? We might surmise that his or her overall performance would be aimed at controlling a perception of himself or herself as a good research subject, as a person cooperating with the experimenter in the interest of science, or the like. What kind of input then would be needed to match this reference signal? It would be that which would most closely match the subject's belief about what the experimenter would want from a good subject. That would be for the subject to report as accurately as possible whether he or she had been touched by one point or two. As long as accuracy had priority over a definite decision, you could expect the subject to say he or she was uncertain whenever the two signals were not sufficiently different to make a definite judgment. However, when the subject was urged to *guess* about his or her experience, a new purpose would gain a higher priority. It would be to make one's best judgment about the probabilities. In the first instance, most people would probably think that the best way to do the task is to report being uncertain, while in the latter case, it could well have been to try to recall, "Now did that last touch really feel different from the one before?" Thus, we reinterpret the data as showing that there is a signal, however faint, and it is used as best possible by the subject in controlling his or her performance to match the instructions as he or she construes them.

In the McCleary and Lazarus (1949) study, subjects were instructed to report which of a set of nonsense syllables they had seen flashed on a screen. The lists were flashed at five different speeds, ranging from slow enough for easy recognition to speeds too fast for recognition. After the initial viewings, the subjects were given an electric shock one-third of the times that certain of the nonsense "words" were flashed. It was found that when the shock-words were flashed too rapidly to be recognized, many of the subjects still showed an increase in their galvanic skin response. The experimenters interpreted their finding as evidence that people can have "perception without awareness."

We must not ignore the fact that the subjects perceived themselves, first of all, to be performing a task. The task had unpleasant aspects to it, but the subjects' job was not to avoid them; it was to go ahead and report the word which was flashed, if possible, while doing their best to tolerate whatever unpleasant experience might be involved. Since GSR is actually a measure of sweating, and since that occurs as part of a larger picture of coping with stress, there is a question of whether the shock was a signal used in word recognition or whether, on the contrary, the "words" became signals warning of oncoming shocks. The latter view makes more sense in terms of behavior as controlling for desired perceptions. There is one apparent difficulty with this interpretation. McCleary and Lazarus (1949) found increased GSR even when their subjects guessed wrongly as to the word which had been flashed. Once more, we can gain some perspective on this fact by considering what the task may have been from the subjects' points of view, in contrast to the way in which the experimenters perceived it.

The subjects had to construe the instructions within the larger framework of controlling their perceptions of themselves as subjects in an experiment. The introduction of shocks enlarged the subjects' job. Their normal way of coping with physical stress like shocks undoubtedly would be to try to avoid them. But in the experiment, this tendency was combined with the job of cooperating. Many people possess principles which command "repression" of painful experience, excluding it from conscious awareness. Therefore, subjects in the McCleary and Lazarus experiment who possessed a tendency to repress signals warning of pain might tend to get those words wrong even though their lower (physiological) control systems were correctly alerting their stress-coping mechanisms. It would be a form of unconscious control, of the same sort which operates in maintaining our balance (to which we never pay attention unless we trip and start to fall).

10.2.3 Perception with Awareness

The really interesting results of the studies which followed in the tradition of Suslowa's (1863) original observations are not those supporting the conclusion that people can receive and use sensory signals without being conscious of them; we really knew that already. Common sense tells us that people frequently chase flies off their ears without being aware of it while intensely engaged in conversation, drive around potholes in the street while thinking about their job, and perform literally hundreds of other actions which similarly are not noticed, because their awareness is focused on other, usually higher-level, variables.

Thus, we are proposing that the question of perception with or without awareness is not decided simply upon the strength and nature of the signal one receives. (Although that is also relevant and is an important topic in itself.) Rather, since there are many perceptions being controlled in a person at any one time, whether some particular one is or is not in awareness would seem to depend on its relation to which other perceptions are currently being monitored. This view does change the definition of the term "perception" to make it correspond with the signal pattern which behavior is attempting to maintain. The traditional view tended to equate perception with what one is aware of, although, as you have seen above, that conception was violated by the concept of "perception without awareness."

One recent attempt on the part of traditional psychologists to deal with the anomalies in the kind of studies described above is Signal Detection Theory (Swets, 1964). Swets began with two concepts familiar from Information Theory: "signal" and "noise." The signal is the information which sensory receptors extract from physical events of the environment, and noise is whatever dilutes or distorts the signal extracted and transmitted by sensory nerves. In Swets' view, the noise is there all the time, and signals are sometimes superimposed on it. Thus, signal-to-noise ratios vary, comprising what we call "signal strength."

Rather than the absolute physiological and perceptual thresholds of earlier researchers, we then would have increasing signal strengths, and the possibility of "perceiving" any given signal would be a function of the relationship between signal strength and the strategy for detecting it. The personal strategy would include factors from the individual's past experience with signals of the type in question, plus "motivational" factors in the reasons why the individual was trying to detect the signal.

Thus, signal detection involves a decision on the part of the observer or subject in an experiment on perception. The observer makes his or her decision as to whether or not the looked-for signal was present on the basis of a *criterion* which incorporates various factors interacting to create the decision strategy. Imagine yourself in various practical situations, such as looking for the outline of an oncoming boat in fog, listening for a fog horn, or deciding whether you are hearing the step of a robber or only the natural creaking in an old house. Researchers in this field have tried to distill the processes at work in such practical situations into purified laboratory conditions such as the following.

Goldstein (1980) outlines some prototypical experimental designs in which a subject is asked to decide whether or not a signal is present under experimental conditions which might be varied along a number of different dimensions. Examples of such dimensions of variation are these: (1) varying the probability that the signal is present on any given trial; (2) varying the strength of the signal on different trials; (3) varying the motivation of the subject (presumably) by manipulating a "payoff" matrix of rewards and/or punishments for correct and/or incorrect decisions.

An example of the last type of variation, as described by Goldstein, is one in which a subject is asked to answer "yes" or "no" to repeated presentations of a signal of constant strength under the conditions of a "payoff" matrix in which, for instance, the subject is paid $1.00 for a "hit" and 20 cents for correctly noting no signal, but loses $1.00 for a "miss," and 20 cents for a "false alarm." Under such conditions, the subject is rewarded and punished more, respectively, for getting or missing a signal, than he or she is rewarded or punished for detecting no signal or making a wrong guess. Under such conditions, the typical subject increases the proportion of "yes" answers. Thus, it can be seen that an observer's decisions might change even when the signal is held constant, as he or she changes the decision criterion. The results of performance under such varying conditions can be plotted as a function called the "receiver operating characteristic" (ROC).

Goldstein (op. cit.) concludes that Signal Detection Theory allows all such variability in conditions to be accounted for in the observer's criterion for a positive decision, and the signal-to-noise ratio can be plotted against various criteria to show a person's ROC under given conditions.

10.2.4 Conclusions Regarding Current Perception Studies

Notice that, while the recent enhancements of research on perception enlarge the scope and methods of studying phenomena such as those Suslowa (1863) began exploring, they continue to incorporate the assumption that such things as "motivational factors" are like forces of nature, which alter peoples' performances from the outside. We have already proposed an alternative view—that the lower control levels have their reference signals (read "criteria" in this case) set by output signals of the highest level currently acting in the individual.

Therefore, the varying experimental conditions described by Goldstein (1980) should be expanded further. Rather than simply assuming that all subjects in an experiment (of the type Goldstein described) "respond" in the same way to the "payoff" matrix, we ask a control-theoretical question as to what the subject's purposes are in being in that setting in the first place, and how that is involved in his or her stance toward the "payoff" matrix (as well as all other "motivational" factors).

The most interesting facts from experiments such as those of Suslowa, Miller, and Lazarus and McCleary, and the more recent studies in information and signal detection theory thus seem to be the remarkable sensitivity to faint signals which people can display in a variety of conditions, and the ability of the currently dominant control system to compute the particular signal needed for its function within the "noise" of all of the signals currently coming into the brain. (How does the mother detect her baby's cry during a noisy party?)

This brings us to the subject of what is a signal—or what is information—as the sense receptors provide it to the input side of the control systems which are active at any given time. There are several current schools of theory about the nature of the signals which comprise the input side of our circuitry: Information Theory (Shannon and Weaver, 1949), Signal Detection Theory (Swets, 1964), and various advances in psychophysics comprise major areas of investigation. The interested reader can go deeper into the subject than would be suitable here. However, these theories all appear to start with the assumption that there is a stimulus *outside* the organism which sets reactions in motion within the organism, contrary to the control-theory view that the organism is always "doing something" already, and that signals coming into the various control loops of the body are reflecting the transactions between controlled variables and environmental disturbances.

10.3 Perception as Input of the Control Function

What is being controlled when, as we asserted in the model presented in Chapters 3, 4, and 5, control systems control their perceptions? There the answer was that control systems work to obtain and maintain a match between reference and perceptual signals. But there are many separate steps in this process in terms of the neurology involved. First comes the functioning of sensory receptors, or neural transducers as they are sometimes called.

Various forms of energy in the environment impinge upon the organism and are converted to neural signals by the different sensory receptors of the body: the rods and cones of the eye; the skin receptors for temperature, vibration, etc.; the organ of Corti of the ear, in which sound waves are transduced to neural signals; the taste buds of the tongue; and the smell receptors of the nasal membranes. These receptors comprise the informational interface between the body and the external environment, just as the skin constitutes the topographic interface.

The term "stimulus" would most appropriately refer to the impingement of environmental energies upon the body's transducers. However, that term must be liberated from the conception that events of the environment *cause* given reactions in the body. Instead, when transduced into neural signals, they become the inputs which the body's systems work to match to their appropriate reference values. (The signals themselves probably are not single trains of impulses, but trains flowing in groups of fibers in parallel—treated as *units* at the next higher level.)

There is a fertile field for future research by young psychologists in the psychophysics of how energy sources in the environment are transduced by the different kinds of sensory receptor cells. This work has proceeded rapidly in recent years in many neuropsychology laboratories. For example, it is a fairly secure notion that light quanta affect molecules of rhodopsin, stored on the outer portion of rod cells in the retina, in such a way as to change the cell's membrane potential and initiate a neural signal, although some of the details of the biochemical to neural transformation remain to be fully worked out. The same could be said for many of the other sense receptors.

10.3.1 Perception as Behavior

As long as the study of perception remained fairly separate from the study of behavior, there was no reason to look to studies of perception for suggestions about the nature of behavior. Control theory makes the study of perception central to understanding behavior. As an example of how understanding perception can help us understand behavior, consider some experiments done by Rosenbaum and his colleagues (1986, 1987) on people's ability to produce sequences of "responses." Rosenbaum, et al. (1986) found that people are able to say sequences of letter sounds (such as "cee," "aee," and "vee") at rates of 3.5 to 4.0 sounds per second, but no faster (without beginning to make errors). Rosenbaum (1987) also found that people are able to produce errorless sequences of finger taps at about the same rate—4 taps per second. Both of these findings were interpreted in terms of the time required to turn the mental representation of the sequence into the actual motor outputs which produce the behavior; the limitation in the rate of response was hypothesized to be due to the processing required to produce output.

As control theorists, we see it differently. The subjects were requested to produce a sequence of inputs (sounds or taps), not outputs. The subjects might not be able to perceive a sequence if the events which make up the sequence occur faster than 3.5 or 4 per second. The fact that the limitation is nearly the same for both sounds and taps (which have very different output systems and, presumably, different dynamic capabilities) suggests a general limitation in the ability to perceive sequence.

The control-theory model predicts that all sequences, auditory, visual, or proprioceptive (taps) are perceived at the same level, and hence at the same rate. There is evidence that events cannot be perceived as a sequence if they are occurring at too fast a rate. Kolers (1972), in an aside in a paper on visual motion perception, notes that a sequence of letters (shown one after the other) cannot be seen as a sequence if they are presented faster than about 3 per second. This occurs in spite of the fact that the individual letters in the sequence can be perceived. Similar evidence exists for audition. A sequence of auditory events (tone, noise, vowel sound, etc.) cannot be heard as a sequence if the elements of the sequence occur faster than about 3.5 or 4.0 per second (Warren, et al., 1969). It would be very interesting to do an experiment to see if the same result occurs with taps on the finger tips (the inverse of tapping fingers on the table). It is very likely that people cannot perceive the sequence of taps if the taps occur faster than about 3.5 per second.

There is clearly more work to be done before it can be established that a behavioral limitation is the result of a perceptual limitation. But research of this kind would be an excellent approach to testing control theory as an alternative to conventional behavior theories.

10.3.2 Hierarchical Relationships Between Perceptual Classes

One of the classic techniques in the study of perception is the method of adjustment. The subject is asked to turn a dial or handle until some perception is produced. The dial or handle affects some property of a stimulus (its frequency, intensity, etc.). The subject might be asked to turn the dial until a light is "just visible" or until the pitch of a sound matches the pitch of another. The subject is asked to control a perception relative to a verbally defined reference.

The method of adjustment can be used to look at different levels of the perceptual hierarchy. This is done by having the dial affect the rate at which stimuli are presented to the subject. For example, the dial could affect the rate at which a sequence of single digit numbers is shown on a computer screen. At the low end of the dial, the rate of number presentation is very slow—each number comes on, and stays on, for, say, 5 seconds, until the next number comes on. At the high end of the dial, the rate of number presentation is quite high—each number comes on for only 1/20 second, resulting in blur. The subject can adjust the dial, starting at the high end, until it is possible to see the numbers in the sequence. The fastest rate at which this can occur gives an estimate of the time required for sequence perception. As noted above, it probably would be about 1/3 second.

If two sequences are presented next to each other on the screen, it should be possible to slow down the sequences even further and detect a relationship between them, if one exists. For example, there could be a functional relationship where the numbers in one sequence are twice the size of those in the other. To make sure the subject is detecting the relationship (and not just a sequence of pairs of numbers), a non-repeating series of numbers, instead of two sequences, could be used.

Some initial attempts to look at the hierarchy of perception using the method of adjustment appear quite promising. It is compelling to be a subject in these experiments, and see perceptions appear and disappear as the rate of events change. It is particularly compelling to see that a higher-order perception (like a sequence) cannot be perceived (if the rate is fast enough), even though the elements of the sequence (the numbers) can be seen just fine.

A related area of applied research deals with the extent to which people can develop higher-order control systems to interpret faint signals for various practical purposes—for example, by wine tasters, whose trained senses of taste and smell can perform discriminations which seem nearly miraculous to untrained laypersons. This topic involves an overlap of the traditional areas of neuropsychology, learning, and perception.

Another question which ought to spark the interest of a new generation of researchers is how given sensory signals become amplified (if they do) to create the error signal in a particular control system so as to capture consciousness away from the perception which was previously being monitored. Almost a century ago, the pioneer clinicians Sigmund Freud and Carl Jung noticed that the "stream of consciousness" gives clues about problems with which an individual is currently struggling. Freud developed a major treatment procedure, called the "method of free association," upon this observation. He maintained that in using this method—reporting the sequence of thoughts flowing through one's mind—a person would invariably touch upon topics relating to his or her unsolved problems. A control-theory suggestion might be that the "stream of consciousness" consists of shifts in attention from one control system to another, according to the needs for amplifying perceptual signals in systems where error signals are being corrected. There has not been much advancement with this topic since the days of Freud and Jung. Some further speculations on it are offered in Chapter 16, in a discussion of consciousness.

Finally, a further area for research on "perception without awareness" pertains to this theoretically and practically interesting question: If people really can be persuaded more readily to buy things by subliminal information than when the advertising is "in the open," why would that be? It might be that the research on this topic should be redone with the aim of answering that question.

10.4 Optical Illusions and Other Features of Visual Configuation-Control

Psychologists in the traditional field of perception have discovered many curious features of (especially) visual experience, which intrigue us because they reveal limitations or distortions in visual inputs. Consider ambiguous figures. Look at Figure 10.1, called a Necker cube.

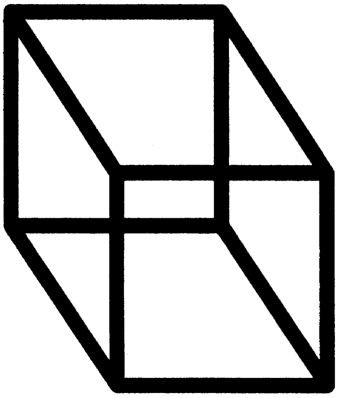


Figure 10.1 Necker cube

To most people, the Necker cube appears solid, or three-dimensional, even though it is simply a set of lines on paper. If you keep looking at it for a while, you'll notice another interesting feature. The configuration appears to change, so that at one moment you seem to be looking down at the top of a solid, glass cube, then at the underside of the top of an empty box. Alternatively, you could be looking up at the underside of the top of a glass cube through its transparent front surface. What is happening here?

What is the controlled condition in this case? It must be more than simply to experience sensations of different light patterns. We look at the illustration to see *something*, that is, to identify an object in the configuration currently under control. What does it mean to say that a configuration is under control? The task seems to be to categorize it. However, the different descriptions above "interpret" the configuration equally well. Our visual experience at this moment resembles that of looking up a word in a thesaurus, and being presented with several synonyms; we have several options from which to choose. In this case, the control of one's perception consists in the "action" of identifying or classifying the configuration.

The above explanation does not go beyond the traditional approach of simply describing the alternative interpretations we can make, except in one way. It suggests that the number of different interpretations depends upon the categories which the person has to apply. A young child, or a person (perhaps living in a primitive culture) who has never seen either a box or a glass cube, should not have alternative interpretations for this configuration. (The evidence for or against this hypothesis may already exist in the work of some anthropologists or child psychologists, although we are not aware of it.)

The same line of analysis can be applied to other well-known optical illusions, the subject of "perspective," and judgments about the size of objects. Experiences which in the traditional view have been regarded as tricks played by the perceptual apparatus on the mind, have, even there, been shown to result from *interpretations* of the visual signals in terms of other portions of a person's knowledge. (For "other portions," read category-level perceptual variables.) Further enlightenment on the actual mechanisms underlying our experiences of such things as the apparent convergence of railway tracks in the distance must await the unraveling of the actual computations of perceptual signal functions by the circuitry of the third to seventh orders, in particular.

10.5 Conclusion

The trend of the argument in this chapter has been to suggest that the phenomena heretofore described in the study of perception will ultimately be seen as the details of the types of variables controlled by the different orders of the control-system hierarchy. In that context, the illusions, distortions, and functions of perception cannot be treated independently of the individual's highest purposes, operating at the time the "phenomena" are observed, and his or her unique repertoire of subordinate control levels.

Chapter 11

Higher-Order Control Systems: Personality and the Self

11.1 Some History of the Idea of Personality

The topic of personality grew up in psychology as the study of the relatively stable aspects of a person's behavior. The stable aspects of behavior show up as habitual attitudes, moods, styles, or patterns of action displayed by the same individual over extended time periods and different situations. The terms used by observers who know the person well (which may or may not include himself or herself), for these consistent patterns, comprise the description of personality. Such descriptions often employ adjectives like "friendly," "generous," "taciturn," "stingy," and their opposites. These terms express a general tendency; for example, we say, "X is a friendly person," thus categorizing something we think we notice running through many of X's actions.

However, in recent decades this simple, common-sense notion has become more complicated by the work of some professional psychologists. As stated in a recent article in *American Psychologist*, "For the past two decades the person-situation debate has dominated personality psychology and had important repercussions in clinical, social, and organizational psychology." (Kenrick and Funder, 1988, p. 23)

What is the person-situation debate? It is, briefly, a controversy over whether personality is a true aspect of human nature, or a misperception resulting from a peculiarity in the way people tend to explain experiences to themselves. Do people generally act in individually characteristic ways, even in the same environment, because of their separate needs and motives? Or do we act predictably in many situations because the environment in each situation tends to require the same action from anyone in those circumstances?

Considerable evidence has been gathered in seeming support of each of these opposing views. For personality, for example, a research measure called the "guess who technique"—used extensively to study social relations among grade school children, with questions such as "who is the most popular," "who is the quietest," and "who is the friendliest"—has found regularly that children show considerable agreement in making such identifications (Hartshorne, May, and Shuttleworth, 1930; MacFarlane, Honzik, and Davis, 1937). This suggests that grade-school children already have enough consistency in some characteristics to enable peers to recognize each other by them.

On the other hand, attempts to use established personality measures for various kinds of practical applications have frequently proved disappointing. An example given by Mischell (1984) involves use of personality ratings by trained judges, standardized personality interviews, and ratings by an assessment board to predict the future success of Peace Corps teachers in an African country. Although there was good agreement among the raters and methods, their predictions were only slightly better than chance when checked against measures of actual performance on the project.

Still another kind of criticism of personality formulations as means of predicting what people will do involves the "fundamental attribution error" (Jones, 1979). That is the case in which people think they observe stable personality characteristics in others which don't really exist.

It would seem that the answer you choose in the person-situation debate largely depends upon how much weight you give to what kind of evidence—that is, unless the entire issue is a false one resulting from an incorrect basic assumption about how people work. That it *is* a false issue is the position we intend to maintain below, as we discuss the problem of personality from the point of view of control theory. First, we shall take a short historical tour of this field of psychology.

11.1.1 Early Clinical Formulations

The word "personality" wouldn't exist if many people had not at some time believed that each of us has a core of relatively long lasting (if not permanent) characteristics which give a unique stamp to our behavior in many different circumstances. Our daily, common-sense observations about ourselves and other people are full of illustrations. I might say that I am a "friendly but somewhat shy person." Immediately then, you could make certain predictions about my behavior in many different situations, not just the one I was in when I said that. However, there could be many qualifications. You might not believe that I have an accurate picture of my own characteristics. Or you might suspect that I want you to see me that way because I think it is a good way to be. Or you might believe that I would not want an accurate picture of my characteristics to be public knowledge, even if I knew it accurately. Or you might doubt whether your definition of "friendly but shy" would be the same as mine in actual practice. But, in spite of all that, you might still believe that there is some kernel of fact in my self-description, so that, upon meeting me, you could expect not to be attacked or insulted, though not necessarily greeted first. You might think it reasonable that people do possess at least a few basic consistencies which can be equally well observed by oneself and those around one.

This common-sense view of personality was taken as a starting point by many of the early writers on the subject. Instead of arguing about whether it is a true fact, they simply took it for granted, and began theorizing about why it is so, or what consequences it has in practical life. (The notion that I would describe myself first and then make my actions match my descriptions is already a more complicated kind of theory, although easily understandable from a control-theory perspective, as shown below.)

The early view is illustrated by Henry Murray and Clyde Kluckhohn (1948) in their book on personality. They called Freud's psychoanalysis the "first comprehensive dynamic theory of personality." (Interestingly, Freud himself did not use the term "personality" much in his writing.) Murray and Kluckhohn credited Freud with showing that many seemingly unrelated behaviors may be different only on the surface. Under the surface, the same underlying set of needs and aims are producing the various behaviors which make up the personality of a person. They then used the term "personality" to refer to "the functioning of the individual as a whole." Their book of readings on this subject includes contributions from many different points of view.

Freud (1905/1953) contributed to the subject with the introduction of a broad-scale conception, the personality *type,* which he believed to include all human beings in one or another of three main groupings, based on the way in which a child was cared for during early development. He argued that many behaviors can be understood as separate expressions of the same underlying tendencies in a person's actions. For example, he felt he had observed that, if a person's early development lacked full satisfaction of the infantile need for normal maternal nurturing (and everything that implies), then the person would likely become fixated as an *oral type.* Because the mouth is originally the main avenue of both pleasure and survival, inadequate oral satisfactions would produce habits of persistent striving for fulfillment. An individual of the oral type would develop a tendency to be constantly *incorporating* things, greedily. Or he or she might literally "need" to be frequently getting something into his or her mouth.

Freud's second personality type was the *anal type,* which develops at a somewhat later age in children who get through the "oral stage" all right, but are mishandled somewhat later when their developmental preoccupations shift from a "mouth orientation" to achieving voluntary control over body functioning, as in "potty training"—the learning to control anal sphincters until appropriate times. Overzealous parental pressure during this period would lead to fixation upon *retaining* kinds of activities: "stinginess" instead of "greediness."

Freud called the third personality type the *genital type.* The child who developed normally through the periods of oral and anal attention would become "genital," meaning that he or she would show personality tendencies characteristic of *loving* and producing, instead of acquiring or retaining. We might rephrase Freud's hypothetical oral type in control-theory language as an individual showing many behaviors suggestive of principles ("values") implementing various incorporation-programs, presumably organized early in the development of higher-order neural circuitry. We might speculate that such systems were organized as a result of chronic error signals in the perception of the variables which are part of "normal nurturance." Freud's other types might be similarly rephrased in control-theory terms.

Simply rephrasing Freud's hypothesis in modern terms does not, or course, prove anything. However, it does immediately reveal a difficulty which contains an exciting opportunity for research. Plooij (1987) and Rijt-Plooij and Plooij (1987) have provided strong evidence suggesting that normal human and primate development only reaches through the first four or five orders of perceptual variables by the time Freud believed "orality" can become fixated. Thus, if "orality" refers to such a high-level variable as a principle, either it must develop considerably later than Freud thought, or else it describes distortions in abnormally developing lower-order systems which are later expressed as a principle. For example, a child whose mother does not provide normal satisfaction (for whatever reasons) of his or her needs for using the mouth would develop chronic error signals in the third- and fourth-order control systems of sucking, tasting, and exploring with the tongue. Systems of the next level then would become organized so as to be constantly alert to get objects into his or her mouth when the child becomes old enough to do this by himself or herself. Later on, noticing the behavior, the child would formulate values "justifying" these habits.

A future researcher could describe the different versions of lower-order control which develop under various abnormal conditions, and then could look to see whether they can be categorized along the lines of different pathological principles. Next, the researcher could look for the ways in which higher-order perceptions might develop to control the use of these distorted habits of action, and analyze them for parallels with Freud's hypothesis. Such research would have the possibility of confirming (or disconfirming) Freud's hypothesis in a way which has never been done previously, because Freud developed the hypothesis by reasoning backward from the reports of adult patients whose true childhood development could only be guessed at. It would also have important practical applications, such as leading to improved methods of predicting when a child's early development was getting "off the track."

Although Freud thought that his three personality types covered all of the possibilities, one of his followers, Erik Erikson (1950), built upon Freud's ideas, and formulated eight *developmental stages* through which individuals grow toward full maturity. Erikson's theory did not emphasize the idea of personality types so much as the idea that developmental problems at any one stage can distort subsequent development and produce a chronic abnormality in a person's behavior. His views have had a major influence in the specialty of developmental psychology.

Another early psychiatrist/psychologist, Carl Jung (1923), introduced a different scheme of personality types. Jung's theory was of a complicated sort. He believed inherited characteristics of temperament like introversion/extroversion, feeling/thinking, and sensing/knowing formed the basis of types into which personalities develop. For example, a person of the "extroverted/thinking" type would generally approach situations in an intellectual and dogmatic manner, while a person of the "introverted/feeling" type would tend to be silent, inaccessible, and hard to understand.

Still another approach was taken by the American psychologist Carl Rogers (1954, 1959, 1974), who was both a clinician and an academician. He brought clinical and research methods together on the subject of personality, and contributed to the application of the "self-concept" as the main focus of study in this area. He emphasized the uniqueness of each individual, and deplored the typing of people. He also maintained that the biological survival mechanisms, including instincts and learning ability, can be summed up in the statement that "the organism has an innate tendency to realize the potentialities of his or her Self."

11.1.2 Research-Based Approaches from Academic Psychology

If someone makes the statement that you have a "warm" personality, this indicates a common aspect of many different behaviors in many different situations. Warmth could be considered a personality trait. Many early personality researchers, in contrast to the clinicians, preferred to work with traits, because they could be analyzed more simply. A whole collection of such trait descriptions comprise the personality sketch of an individual. The separate items of the description—traits—frequently are represented by adjectives such as honest, sociable, moody, hostile, organized, patient, tense (and their opposites).

Two psychologists who contributed major work in the use of traits in personality research were Gordon Allport (1960) and Raymond Cattell (1957). Allport organized pictures of personalities based on combinations of traits, and Cattell developed advanced statistical procedures for combining and objectifying the measurement of traits, and for attempting to predict behavior from these descriptions. However, trait-based theories, and finally all of personality research, began to come under attack in the person-situation debate, as noted above (see Mischell, 1968; Mischell and Peake, 1982, 1983b).

When the conception of personality as a collection of traits came under attack, it was because the more detailed kind of modern psychological research had produced quite a number of studies suggesting that the traits observed might have existed more in the expectations of the observers than in the subjects. This was an alternative explanation, then, for the appearance of individual consistencies. The following kinds of *methodological mistakes* could have been involved in drawing incorrect conclusions about traits, according to these critics:

(1) Different observers often cannot agree on what traits a person has, unless (in some subtle manner) they receive instructions on "what to see." That is not to suggest that earlier investigators were dishonest, only that they had overlooked flaws in their crude investigative methods.

(2) When different observers have agreed, and their observations have been protected against external influences, it could still be the case that the observers independently share similar biases. For example, various studies have shown that middle-class people tend to see lower-class people as having "loose morals," even when there is no evidence to support this prejudice.

(3) Psychologists who took a strong position in favor of the influence of the environment on behavior argued that what looks like underlying consistency in the behavior of a person in different situations actually might be a result of the likelihood that most individuals find themselves repeatedly in situations where similar behaviors are called for.

Eventually, both sides in this debate began to modify their arguments, conceding that there is *some* consistency in the behavior of most people, but that in many situations, persons with very different personalities act similarly, because it would be dysfunctional (and thus a sign of psychological disturbance) not to. Despite this mellowing of the debate, however, a recent reviewer of the entire subject (Perven, 1985) commented glumly, "At this time, neither trait nor situationist theories do a terribly good job of predicting wide ranges of individual behaviors over varied situations, or of helping us to understand both stability and change in personality functioning."

11.2 Personality in the Control-Theory View

You have seen that the subject of personality is a topic of such controversy in contemporary psychology that some psychologists doubt that the concept is of much use. When confronting a confusing situation like this, it is useful to employ the habit of asking, "What is the main purpose?" (Of the efforts involved in the confusion.) Thus, we can stop and ask what purpose is being aimed at by the professionals who study the subject of personality.

Recall that in Chapter 1 we pointed out that texts of contemporary psychology describe it as a science aimed at "prediction and control" of behavior. There is an implication in that expression meaning that the psychologist studies the behavior of *someone else*. The experimenter (whether you, me, or some third party) is considered to be interested in controlling the behavior of another person, the *subject*. Notice, however, an embarrassing confusion in the grammar. In English grammar, a subject acts upon an object. But psychologists call the people in their experiments "subjects," even though they are acted upon, because the word "object" also means "thing," and we are embarrassed to admit that we treat people like things (even though that is an all too common occurrence).

I (RJR) propose that this confusion is not completely innocent, but expresses some uneasiness about the traditional approach to research, in which the investigator regards himself or herself as totally uninvolved in the phenomena which he or she is observing. Robert Rosenthal (Rosenthal and Rubin, 1978) has reported a large number of studies raising serious doubts about the validity of this assumption. His work on the interaction between investigators and subjects in psychological experiments shows how readily research findings can confirm the prejudices of the researchers. The mechanism by which this happens does not have to involve dishonesty on the part of the researcher. It involves the perceptions which the subject is attempting to control relative to his or her own reference values in the situation. That may well include what he or she thinks the experimenter wants of him or her. We shall explore this issue in the chapter on social psychology. For the present, we shall argue that the material of this chapter is better served when the investigator is identified with the subject.

By now you are familiar with the theoretical arguments as to why people cannot control each other's behavior. Why then study psychology? Because most of us have considerable difficulty in controlling the events we would like to control. Hence, there is no lack of the need for a better understanding of how people function in controlling what we *do* control. (We can drop the word "prediction" from the traditional formulation, because it is already contained in a proper conception of "control.") What we come out with is a view of psychology as the study of how people control their environments (the conditions of their lives), rather than the study of how people may be controlled.

With this perspective, the "person-situation debate," which we noted at the beginning of this chapter, becomes a false issue. The person-situation debate is really a debate about whether the person or the environment "causes" the behavior observed in the experiments around which the debate revolves. However, when we view behavior as people controlling (counteracting) disturbances of their reference perceptions, we see that changes in the environment cause deviations in the variables of the environment, not in behavior; behavior causes the condition of the environment to return to the individual's reference state (when successful).

Thus, we can redefine the study of personality as the exploration of the higher-level control systems with which we control our environment. For example, if a person says, "I'm hungry," and someone else then runs out to a store and comes back with food for him or her, would you say the first speaker controlled: (1) the second person, or (2) the perception of hunger pangs in himself? A possible theoretical answer would be that the person controlled (2) by making his or her statement. But that would not be strictly correct in a precise definition of control, because the verbal statement did not cause the hunger pangs to disappear (think of the person making the statement with no one else around), unless we add the conception of a hierarchy. Neither was the second person controlled by the statement (imagine the same situation again, with the second person saying, "Why don't you get yourself something to eat?").

Imagine the same event happening on several different occasions. A psychologist might then say that the first person has a "manipulative" personality, or a trait of "manipulativeness," and that the second person has a trait of "dependency." Now, if both parties only show this pattern of behavior when around each other, and not when around anyone else, you have a good example of the kind of specialized observation which has fueled the person-situation debate.

Let us re-examine the situation as an issue of controlling perceptions. The speaker first perceives hunger pangs. At this point, the statement might have been simply a case of thinking out loud—labelling, or controlling the cognitive identification of, the physiological perception. When the other person ran out to get food, it may have been a surprise on the first occasion. But once it has happened, that new perception becomes part of the larger controlled perception, "things to do when I'm hungry." (That is: "If I complain about my hunger, maybe Y will go and get me something to eat.") Whether this new addition to one's repertoire of "getting food" remains a *program* involving just that one other person or develops into a general *principle* would depend upon whether it works in other situations with other people. That, in turn, would affect its likelihood of being identified with a trait (such as "manipulativeness") by a psychological researcher.

The second party in the situation is controlling an error in himself or herself when the first person speaks. Perhaps he or she has a principle of valuing the pleasure of the other (for any of dozens of possible reasons). Such a value might originate from any of a number of different principles.

From this perspective, personality is a common-sense, rather than a scientific, topic. It does not need to be precisely defined, because it is not a precise concept. The controlled variables of the higher-order control systems can be more precisely defined and measured, as is already being done with lower-order variables. A more measurable concept would seem to the one called the "self-concept."

The self-concept is not an invention of control theory. It has been in use for quite a while, with many interesting findings in the accumulated research. It is roughly synonymous with the highest-level system described in the scheme of the human control hierarchy in Chapter 5. Here we add a distinction which is helpful in examining the research findings in this area. Robertson and Goldstein (1986) proposed that there are two aspects of the self-concept: as an agent, and as the product of that agent. These aspects often are mixed together in the literature. We shall refer to the *active* aspect as the "self system"—the control system controlling the self-image of a person. We use "self-image" to refer to the perceptions about one's own nature which a person keeps under control. This does not mean that all aspects of the self-image are in a person's conscious awareness. Remember that higher-order control systems are, theoretically, neural functions which monitor variables consisting of other neural functions. Before the results of their operations can "see the light of day," they must "call for" perceptions on the level of actions—the actions of talking and doing. Actions can be interpreted in either of two ways: in terms of the variables controlled in the environment, or in terms of hypotheses about the acting person's *intentions*. Most people use the latter option most often. That is how one's friends can "see" a characteristic which a person may not perceive in himself or herself, just as a person might also perceive characteristics in himself or herself which others don't see.

In other words, one can be controlling a condition without knowing it, just as one can sometimes think he or she is controlling something which he or she isn't. Furthermore, while we may call one's own theory about oneself the self-image, that term really refers to the *variables*—the neural functions—rather than the words we use to describe them. You might think of one's knowledge of one's self-image as being like the notes in a musical score or the written programs of a computer: they are descriptive of what the performer does (or can do), not the performance itself.

In a practical sense, many controlled perceptions of the self-image can be named identically with traits which are discussed in the psychological literature. A major difference, however, is that a controlled perception is defined by the "test for the controlled variable," which asks, "Does the person act to restore the prior state of the perceived-condition when it is disturbed?" The concept of *traits* never was defined in this way. Furthermore, the word "traits" is ambiguous. Sometimes it refers to descriptions of habitual actions of a person, not the principles which the actions serve to implement.

Here is a way you can make the "test for the controlled variable" (of someone's self-system) yourself. When a friend describes an aspect of his or her own self-image (that is, says he or she has a certain trait), disturb it by contradicting him or her. For example, one time a friend of mine said, "I am a very quiet person..." I interrupted her and said, "No, you're not." She corrected the "false perception" indignantly: "Why, I am too." You easily can create several versions of this experiment to try for yourself. Many variations of the experiment have been repeated, both formally and informally, with quite consistent results. (See Robertson, Goldstein, Mermel, and Musgrave, 1989.) Likewise, when a person fails to correct a would-be disturbance, we can infer that the perception we thought the person was controlling was not, in fact, under control.

We now consider some of the features of the controlled perceptions comprising the self-image which have been suggested by earlier research. These can be grouped into broad categories: *self-esteem*, *self-attributions*, and *self-attention*.

11.2.1 Self-Esteem

There are many studies suggesting that people act in ways consistent with their level of self-esteem (Carver and Scheier, 1981, especially pp. 210-212 and 255-259). People who don't like themselves very much sometimes do things of which they themselves do not approve, seemingly keeping their level of self-esteem constant. (And people who *do* like themselves also act in ways which hold their level of self-esteem constant.) This may sound strange, until we consider some findings concerning various kinds of deviant persons. For example, professionals working with criminals have reported that many do not approve of themselves, and they sometimes say they do bad things because they are bad. Think of what this means from within the person's own point of view. Imagine the following: "I like that car (I'm looking at). It is not mine... but bad people take things which aren't theirs.... I am bad... so it is consistent for me to take it." There would be no error signals from an honesty-principle to produce conflict and block action in this particular person.

Remember that a person does not have to *think* the above in order to control perceptions which we, as observers, would describe with those words. This is a very important point to remember, because of its practical implications. A great many quarrels arise when a person does something which offends or injures someone else, and the offended party concludes that the other *intended* to injure him or her. In fact, the offender in such instances usually wants only to keep some perception of his own under control, and is ordinarily not aware of (or concerned about) the other's controlled-perceptions at all. For instance, right now I am annoyed that a neighbor left his car parked in front of my house when the street cleaner went by today. But he was controlling his own perceptions well enough to move it before the police got there to give it a ticket. Now I must choose between trying to control either of two different perceptions. The one I really want controlled, how to get such a car moved in time for street cleaning next time, can involve a lot of work. The other is a "cheap" substitute of indulging the feeling that "my neighbor is a bad person because he didn't worry about my needs." The latter perception is much easier to control (all that is needed is to assign the category "bad person"), but it does little for my overall well-being.

In the previous example of the car thief, two different hypotheses could be formed about what perceptual variable the thief is controlling. (Though neither one could be tested unless we had the opportunity to disturb it.) In the one case, we would hypothesize that he or she controls only perceptions related to his or her immediate desires, and cannot control the higher-order perceptions involving what we call "consequences." In that case, his or her self-esteem could be either high or low; it is not directly involved in his current action. In the other case, his or her self-esteem might be the variable "corrected" by the delinquent action. Clinical reports and a number of research studies have noted delinquent acts following a show of affection from a parent, foster parent, or parole officer. One explanation has been that the affection felt "wrong" to the offender, so he or she took action to restore his or her more familiar perceptions.

11.2.2 Self-Attributions

"Self-attribution" is a term frequently used for those activities in which a person formulates and remembers verbal descriptions of his or her own relatively permanent principle-level reference values (traits). Statements such as "I am (or am not) good at math," are usually considered to be observations which a person has made about himself or herself. But there is some confusion about whether such statements are *descriptions* or *prescriptions*. Seligman (1975) and Seligman and Maier (1967) presented data suggesting that, if a person (or animal) repeatedly tries to control some perception without success, he or she will eventually stop trying, and even when later shown that he or she now could succeed, will tend to continue his or her "learned helplessness." The presumed mechanism is that the individual attributes to himself or herself a trait of "powerlessness," which then becomes the reference setting for the action in question.[1] In like fashion, people who enjoy a lot of success in many activities tend to develop great self-confidence, and to express it in self-attributions such as "I learn most things easily," "I am popular," and so forth. They also act in ways to maintain those perceptions constant.

Thus, the relationship between self-attribution and behavior is the same one called "self-fulfilling prophecy" in other contexts. A tentative explanation for the process is the following. A series of similar perceptions are categorized and the common elements of the category come under control as a variable on the next higher level, being consolidated into a conception controlled by a program. Then, several similar programs are formulated into a principle, and the principle is added to memory, as part of the self-image.

Perceptions which disturb an aspect of the self-image are automatically corrected. The person who perceives himself or herself succeeding in many activities eventually formulates a self-perception such as "I am successful," which requires staying with many difficult tasks until they are mastered. The person who perceives himself or herself frequently failing, or being discouraged, or being punished for experimenting (!) formulates a self-perception such as "I can't do anything right," and can experience an error signal in the system which controls this perception when succeeding at something! Then the action which would correct that error would be to "foul up" often, even at the very point of succeeding.

People tend to categorize their perceptions of each other, with similar results. The process is called "stereotyping" in some psychological contexts, "stimulus generalization" in others, and falls under "person perception," "attribution-theory," and "expectancy-theory" in still others. There have been many research studies using these terms (as if they were unrelated phenomena) (see, for example, Cantor and Mischell, 1979; Jones, 1977; Riley and Lamb, 1975; Rosenhan, 1973; Scheff, 1974; Shapiro, 1971; Taylor and Crocker, 1979; Taylor, et al., 1978; Taylor and Huisman, 1974; Wegner and Vallacher, 1977).

11.2.3 Self-Attention

Self-attention, or self-focus, is a term often used in comparing the effects of monitoring or not monitoring one's self-image upon one's control of the environment. Studies from the contemporary psychological literature which present data on this topic also go under the names of "reactance theory" and "cognitive dissonance theory" in various contexts.

"Reactance" is a term indicating a supposed tendency of people to take action to counteract perceived interference with their freedom of action (Brehm, 1966). In a study of reactance reported by Carver (1977), a sample of university students favorable to a certain candidate for appointive office were divided into experimental groups for separate treatments. In one group, the students were presented with persuasive communications for an imaginary official. This was the control group. The other volunteers were in one of two experimental groups. Both of these groups received the same persuasive communications, but accompanied by threats and "high pressure tactics." Further, one of these groups received this treatment in a room with a large mirror in it; the other group did not have a mirror. Carver was testing whether the "self-focus," which he assumed the mirror would promote, would result in more of his volunteers changing to a less favorable attitude toward the candidate on an opinion survey afterwards. His statistical comparison of the results from the different experimental conditions does show that the group of people given high pressure in the room with the mirror had the largest average drop in favorable opinions. He interpreted this finding as confirmation that people usually reacted most strongly against high pressure in the environment where they could see themselves. The presumed self-image principle disturbed by the high-pressure tactics would likely be something on the order of "nobody tells me how to think."

This reminds us of another, quite ancient, set of psychological experiments on "social facilitation" introduced by Triplett (1897). He reported that people (on the average) will cross out more letters in an old telephone book (for example) if they do it in a room where there are other people sitting and looking at them, even though the others have no involvement with them. This finding is usually interpreted as indicating that many people tend to raise their own standards in the presence of others, even when there is no interaction between them. Carver and Scheier (1981, Chapter 15) discuss various theories as to why this phenomenon occurs. A control-theory explanation is that the subjects' awareness of being watched creates a small error in the self-system (of at least some people), bringing about self-system monitoring of principles relating to performance standards. Otherwise, the reference signal governing how to do the task might be set lower, by a principle such as "trivial activities don't deserve a lot of effort."

If there is a common element in the findings of the two kinds of experiment described above, it would seem to be that people will tend to correct disturbances to their self-image, but with qualifications: the self-image must be being monitored at the time, and only those individuals who have a principle which actually is disturbed in those circumstances will show corrective actions. This latter point is probably why so many experiments which depend upon averaging the results of small groups of people turn out "significant" on some occasions and "insignificant" on others.

A third body of experimentation related to the above topic is "cognitive dissonance research." This term originally was introduced by Festinger (1957), who described cognitive dissonance as a condition in which an individual becomes aware of some contradiction among his or her beliefs or attitudes, or among attitudes and actions. The concept is related to the layman's concept of "hypocrisy," except that hypocrisy is usually assumed to be conscious. Festinger postulated that dissonance can originate unconsciously—automatically—but creates discomfort if it comes into awareness. Festinger did not offer any explanation as to why cognitive dissonance should be unpleasant, but we might speculate that it is because of the error signals which occur in higher-order systems when there is conflict in the levels immediately below. Carver and Scheier (1981, Chapter 17) described many of the studies done on cognitive dissonance, and argued that they all could be interpreted as examples of error-correction in systems at the level of self or principles. It will be interesting to describe some of these studies, as they sometimes found people behaving in ways which, at first glance, seem contrary to common sense.

In a prototypical cognitive dissonance study (Festinger and Carlsmith, 1959), volunteers participated in a very boring task and then were asked by the experimenter to "do me a favor" and lie to a new subject, by saying that the task had been interesting and enjoyable. Half of the volunteers were paid $20 to do this, while the other half were paid $1. They were asked later for their own evaluations of the task. Somewhat surprisingly, those who were poorly paid claimed, on average, to have found it more interesting than did those who were better paid. The explanation offered is that the well-paid subjects experienced less dissonance; they did the favor asked of them because they were rewarded for doing so. The other subjects had to reconcile that they told someone else it was interesting for no particular reason. Hence, they rationalized that it was really somewhat interesting, after all.

Another experiment inspired by the concept of cognitive dissonance was done by Zimbardo, et al. (1965). Two groups of army recruits were requested to "try a new, experimental ration"—fried grasshoppers. One group received this request from a pleasant officer; the other from an unpleasant one. Later, when asked to evaluate the exerience, those in the unpleasant-officer group who had actually eaten the grasshoppers (about half of each group) claimed, on average, to have found them somewhat good, in contrast to the average of reports from the pleasant-officer group. In this experiment, as in the one above, the hypothesis (presumably stated in advance) tended to be confirmed. The results were interpreted to mean that the subjects in the pleasant-officer group didn't experience as much conflict, because they could think they just did it as a favor to a "nice guy," but the other subjects had more dissonance to correct, since they didn't have this reason to fall back upon. Thus they would be more prone to find some good in the experience.

These experiments may well have created error states in self-image variables (in some of the volunteers), which were then corrected by the actions described, as Carver and Scheier (1981) declared. But the experiments always were done without performing the test for the controlled condition, to determine what the subjects were actually trying to control. Therefore, we can only wonder what portion of the results were due to the subjects' controlling perceptions involving what they thought the experimenters wanted from them, and their attitudes toward that.

11.3 Applications

When I (RJR) have given lectures on psychology to parents or other community groups, sometimes I have been asked questions such as the following: "What does spanking a child do to their personality?" "What do you do with a shy person?" "How can I make my boyfriend or girlfriend change?" When I was young, naive, and arrogant, I used to reply to such questions, "I can't answer that, because it is a meaningless question." Then I would proceed to educate the questioner in the philosophy of science. Eventually, I came to learn that consumers of psychology (like consumers of any science) are usually looking for help from it, not instruction in its philosophy. It is true that the manner in which help is asked can reveal a great deal about the speaker's conception of the kind of help which science has to offer. And the assumptions underlying the question affect how much help can be obtained. (For example: (1) How can a man fly like a bird? Answer: He can't. (2) How can an object fly in the air? Answer: By causing the air to move faster on the upper side than it is moving on the lower side.)

How much help psychology can be depends on whether our scientific knowledge applies to what people want to do. Taking another look at the sample questions from my lectures, we notice that they implicitly express the questioner's belief that psychology deals with how to "predict and control" human behavior —exactly what the introductory chapter in most general psychology texts says it is about. But what do the questions show about what people want to do? Why does a parent want to know if definite consequences can be predicted for the action of spanking a child? Because the parent wants something: either to guarantee that the child will love him or her, or to guarantee that the child will not grow up a criminal, or to guarantee that the child will become rich and successful, or the like. Why then didn't the parent state the question in terms of what he or she *wants*? (Question: "How can I make my child love me?" Answer: "You can't; but there is evidence that children who feel loved also love themselves, and love those who love them." "Then how do you make a child feel loved?" "You can't; but if you genuinely love the child, there is evidence that, if you show it, then the child will feel it. He or she is built that way.")

In time, I learned how to translate the questioner's wording into a statement about what he or she wanted, and then we could begin a dialogue about how he or she might move in the direction desired. But I could never say what behavior to engage in, because I could never know what the circumstances would be at the time he or she did it. Furthermore, I could never know how he or she would control the perceptual variables which we both might call "parenting behavior." I believe that this is true for any psychologist, or any person of any sort, for that matter.

Why then does the layman ask how to control behavior, instead of how to control results? I have already suggested above that that is what many of us have (mistakenly) been led to see as the nature of psychology. But what if, in fact, psychology *cannot* be about controlling behavior? What if it only can be about controlling *perceptions*? (Of course, you recognize that as an editorial question. It is what we have been claiming all through this book.) It is fair to ask what difference that makes in finding applications for everyday life.

One immediate answer is that you cannot control a control system externally. Its action changes when the environment changes in a way which disturbs the condition the system is trying to keep under control. The only other way behavior changes is for the system in question to get a new reference signal from a higher level in the organism's hierarchy. If you go back over the results of traditional psychological experiments, and their reinterpretations in control theory in this chapter, you will see that they can be understood in this manner.

To perceive a certain kind of personality, then, is not thrust by the environment upon a person. It is a way of categorizing one's observations of other people (and in the same way oneself) so as to be able to control higher-level perceptual variables, instead of treating every situation as if it were entirely new and different. What this means in application is that to know what kind of personality someone "has" does not help you act toward them. What helps you act in every situation is keeping your attention on how well you are controlling what you want to do. If you are not controlling it well, you need to know how *you* are operating, not what someone else "is like."

I suspect that this is what extremely effective people have always done. Unfortunately, effective people probably were that way more by ignoring the psychology of personality than by studying it. Traits or types of personality (if they are observational categories, as we have claimed above) are results of the acts of observing, not facts of nature. If that is so, then such studies are more useful for understanding what observing is like than for understanding what people are like.

Let us make this concrete by moving to the second of the applied questions mentioned above. "What do you do with a shy person?" again illustrates the illusions we have been trying to point out: first, that there is some behavior —some action—which is independent of what the person who is acting wants; second, that there is some condition, "shyness," which, like measles or blond hair, you can "get." (Whether you get it from your genes or your early experience is relatively unimportant, if your concern is doing something about it.) In fact, if you actually engage in any kind of interaction with someone who is said to be "shy," you will find that the "condition" describes all kinds of potential variables, many of which may be totally in contradiction to each other. "Shyness" can be an asset in one sense, or a liability in another. If John often fails to get what he wants because of not speaking up for it, and he calls that "being shy," it is most likely a liability for him. If Mary asks Sam for an introduction to John because she fancies shy guys, it might be an asset.

Before going on to the third question about how to get someone to do something which you want, let's bring in a discussion of one area in which traditional personality research seemingly has been fairly useful: the area of selection. The personnel practices of organizations do seem to have benefitted from applying personality psychology to the job of selecting (and rejecting) people for various position placements. And that activity does seem to resemble what the person is asking for in saying, "How can I get what I want from X?" (The wording is changed slightly, but this still captures the original intent.) The common ground is that the friend, lover, and employer all want something that needs the actions of someone outside themselves. Employers supposedly have discovered that selection is often cheaper than training—getting someone who is already capable of doing what you want, instead of trying to get the person who is there to change—but either way, the ultimate goal is the same.

However, although personnel selection has proven a useful application of psychology, that fact has often been taken to support an illusion. The illusion is that personality testing tells how an individual will behave. In fact, what it does is predict the effect that a group of test scores (from a group of people) will have on the probability of a desired outcome. The employer doesn't want any certain action from any particular person; he or she wants a prediction of the likelihood that enough of the people in a certain group want something which is reasonably in harmony with what he or she wants so that he or she will get it. Once some particular persons are in place, of course, the process of interaction, or mutual training, does take place. It becomes personal interaction again, and the rules are not all that different from those applying to friendship or love relationships. That is, a balance must be struck in which each gets enough of what he or she wants to keep the interaction going. That brings us back to the question of "How can I get what I want from Mary or John?" The answer has been implied in what was said above: it is not so much a matter of what to do with a person "of a certain kind" as it is a matter of getting "what I want and what you want" to match. (For more specific procedures, see Ford, 1987.[2])

There is one other area of application of traditional personality psychology which we shall leave to the chapters on social and clinical psychology. That is the practice of making predictions about the future behavior of individuals (of specialized sorts), which is a highly developed skill or art in the hands of some practitioners.

11.4 Conclusions

Rorer and Widiger (1983), in a review article on "personality structure and assessment," attacked the problem of personality study by going back to philosophy to get to the bottom of the confusion in the field. They set the tone of their approach with a reference to an article by Shrauger and Osberg (1981), which they summarize in this remark: "In general, if you want information from someone (including personality information, presumably), the best way to get it is to ask them.... Assuming that they understand the question, that they have the information, and that they are not motivated to deceive you, that is not only the simplest and least expensive, but also the most accurate procedure." Rorer and Widiger went on to argue that "psychology is burdened with an outmoded philosophy, and a distorted view of science... [in which statistical generalizations from observations of groups typically are used to impute things going on within individuals]."

With the perspective of control theory, we find different kinds of generalizations about personality than those heretofore treated under this topic. Instead of classes of standard actions, or traits, supposedly characteristic of the human species (even though not present in all members), we have the following generalizations about the upper levels of the control hierarchy: the self system controls (perceives, monitors) perceptions at the level below (principles); some of these pertain to its own nature—the self-image, others pertain to the nature of the external environment (generalizations about reality, or, in other words, knowledge!).

Actions resulting from alterations in the reference signals which the self system sends to the systems below it (principles) are called "behaviors." There are literally infinite ways in which behaviors can be "chunked" and named. This has provided endless work for personality psychologists, who tried to "discover" new human "characteristics." An alternative to discovering and naming new characteristics is to explore what variables (in the physical environment) given individuals control in various situations, and how they control them. These variables previously have been considered as part of lower-level behavior (that is, beneath personality), and studied as if they operated independently of the higher levels. For example, in a so-called "perceptual-motor" task (Robertson and Glines, 1985) where the volunteers were to "play a game with a computer" requiring only the physical actions of hitting four different keys, we found them giving an endless variety of "theories" about what the game was. This was regardless of whether they solved the problem of the game or not. Furthermore, some people won the game, but could not give a correct explanation of it, nor of what they had done. Yet only a few of them said, "I don't know what happened." Most of those who solved the problem had a "theory," however wild. On the other hand, there were quite a few who failed to solve the problem, and among them were some who had a workable approach, but said, "I'm afraid to change what I'm doing because I might lose ground." (Similar to "learned helplessness"?) There were others who started to solve the problem, then stopped doing what worked; some of them said, "I'm not good at computer games." (Self-fulfilling prophecy about the self-image? Would they have had cognitive dissonance such as "Maybe I *am* good at computer games" if they had continued until they solved it?)

In view of the results of this seemingly simple experiment (and others like it), we can choose between two alternatives:

(1) Try to test every conceivably named controlled perception of every different person in a given situation, and then try to categorize them. Perhaps that approach would blend the traditional trait-measuring approach with an aspect of control theory, in an attempt to find personality characteristics of people in general. For example, a hypothetical application of this idea to the Robertson and Glines (1985) study, mentioned above, might go like this. Divide the subjects into groups of those who want to solve the problem and those who don't. Then divide those who want to into those who want to because they like games and those who want to because they are competitive. Do similarly for those who don't want to.

Notice two things about the procedure described above. It contains assumptions about traits such as "gameliking" and "competitiveness." To assume that such traits exist in a person means that he or she will show the kind of behavior warranting such descriptions at other times and in other circumstances. We could express the same idea in control-theory terms by saying that people often develop principles which are similar enough from one person to another that we (in society) lump them together and accept common names for them. This is the activity of categorizing, which *does* seem to be a general feature of the human species, unlike "competitiveness," etc., which describe similar behaviors in only *some* members of the species.

Notice that when we began naming categories for the different principles which might be underlying the action of subjects in just one experiment, it appeared that we could go on almost endlessly doing that. Among the people who did not want to win the game, was there one who was showing the trait of "learned helplessness," another showing "dependency," and still another demonstrating "fear of success" or "fear of failure"?

(2) Turn the study of personality inside out, by proposing that researchers examine people's attention to questions like "What do I want and what do I do to perceive that result?" in place of "What kind of person am I and what kinds of characteristics do such people have?" When we take the second choice, we concentrate upon how people *change*—reorganize—rather than what one is at any one moment. For example, with the students playing the computer game, after the experiment was concluded, we continued to recruit subjects, allowing them to vary their own conditions. One was especially instructive. This student was required to choose one among several experiments for the purpose of gaining concrete experience in an elementary course in learning. She chose the computer game. After failing to solve it the first time, she dropped it and went on to a different choice. There was no pressure from her instructor, except that one demonstration experiment had to be finished for course credit. After completing a routine learning task, she returned to the computer game on her own. She failed to solve it several more times, then finally she did. Did this subject possess a trait such as "reactance to defeat"? Or would we be satisfied to accept her explanation in her own terms, that she "wanted to see if I could do it"? What seems to us most interesting about this case is not the question of whether or not her behavior can be classified in terms of some permanent aspects of her personality, but rather the facts of how she worked. Some subjects were offered hints, and, in some cases, explicit instructions for solving the problem, when they failed to do so on their own. The results were variable. In some cases, the persons seemed not to hear or understand the instructions, but continued their futile actions as if they

had been deaf. With this particular subject, no hints were offered. In fact, we didn't even know that she had returned to this task. When she did finally succeed, it was because she had reorganized to control a new perception which she couldn't even name until she was questioned after succeeding. How had she gone about reorganizing? All we know is that she wanted to. In other words, there seemed to be an error in her self-system which might be expressed in words such as "I know I can beat the machine, and I'll keep at it until I do."

Notes

1. Recall our earlier discussion about how even a non-human animal can sometimes show behavior which looks as if it had said to itself, "I have this trait." The controlled variable is a neural circuit, not a set of words.

2. Don't be put off by the title of Ford's book, which probably was intended to get it into the hands of those people needing it most. The book provides a good illustration of the interactive, control-theory approach to personality, in contrast to the traditional, external-observer approach.

Chapter 12

Conflict between Systems and Reorganization of Higher Levels of the Control Hierarchy

12.1 Introduction

The concept of *reorganization* was described theoretically in Chapter 7. There we speculated about how a person's learned hierarchy gradually gets reorganized. This happens when existing systems cannot bring some perceptual variable under control. Error signals increase, intrinsic-system values begin to be violated, and the reorganizing system becomes "turned up." The reorganizing system then injects random signals into the hierarchy until the affected life-maintenance (intrinsic-system) values return to normal.

The current organization of the hierarchy remains relatively stable until the next reorganization is forced by a new loss of control. The individual becomes more complex, or more sophisticated, when reorganization results in the ability to control situations which he or she previously could not. Not every reorganization necessarily has this result, since *any* reorganization which is followed by reduction in intrinsic error signals tends to persist. Thus, reorganization theoretically can result in circuitry which might prove *in*effective on some future occasions, if intrinsic errors happened to be reduced *coincidentally* to the ongoing reorganization.

The above view of reorganization contains complications which are not initially apparent. Different persons can come to control different variables in controlling what would seem to be the same environment. For example, among a group of people playing golf, one could be mainly controlling a desire to see a better score than his last one, another could be mainly controlling a desire to make a good impression on another player, who happens to be his boss. Still another could be controlling a personal value, such as demonstrating that he can outdo any of his peers, and so on. How each person performs does not just depend on his or her technical skill. The way one uses one's technical skill must satisfy all of the principles which that person's self system has called up in that situation at that time. The final result might be any combination of the lower-order repertoires producing the perceptual condition which satisfies the highest-level reference signal.

12.2 Interaction Between Higher- and Lower-Level Control: Influence on Development of the Learned Hierarchy

Consider a classic set of experiments which investigated peer-group influence (or social pressure) on perception, by Asch (1953, 1940) and Asch, et al. (1938). These experiments illustrate the way in which a person's highest-level systems (self and principle) control behavior by setting the reference levels for it, although Asch's studies were not conceived with the hierarchical control-theory model in mind.

The initial experiment, which has been confirmed generally in various versions, was basically simple. The experimenter asked a series of individuals, each of whom thought he was working in a group of peers, to call out their judgments about the comparative lengths of some lines drawn on a blackboard. The "peers" were actually stooges of the experimenter, and they sometimes called "line B" longer when "line A" was really the longer line. Surprisingly, when a majority of the stooges called out incorrect readings, the majority of volunteers tended to go along with the crowd. Some of them (about a third) appeared to go along most of the time. Another 15-25% stood firmly on their own judgments, even when the stooges "pressured" them heavily. The rest of the subjects fell somewhere between these extremes, depending on the size of the majority, how clear the differences in length were, and so on.

Although Asch was not thinking in control-theory terms, his descriptions of how different individuals maintained their independence showed that those who did not go along with the crowd did not all maintain their independence in the same way. The independent subjects controlled many different principle-level perceptions in holding to their own judgments in the face of social pressure. Some, Asch said, made their decisions based upon their confidence in their own opinions. Others held onto their independent judgments, but became withdrawn, and "[did] not react in a sponeously emotional way, but rather on the basis of explicit principles concerning the necessity of being an individual." Still a third subgroup of those who maintained their independence did so with "considerable tension and doubt, but... on the basis of a felt necessity to deal adequately with the task."

Let us attempt to describe the different types of principle for which the subjects in each of the above three groups may have been controlling. In the first group of independents, the controlled variable must have been somewhat along the lines of "My eyes see clearly, it doesn't matter what others say." In the second group, it might have been more like "I have to call things as I see them, even though I might be wrong, because I don't want to be thought of as a wimp." For the third group: "I hate being an outsider, but doing the job is more important." We can imagine how the self-images of the members of these groups would be different, as we might infer them from the individual principles maintained by their overtly similar actions.

Asch noted that those who succumbed to the group influence also gave a variety of reasons which could be classified into separate categories of still different principles. For example, some of the non-independents seemed to act on the principle "The majority must be right." Others really did not believe the majority was right, but yielded in order to maintain a personal value such as "I should not appear different from or inferior to my peers."

How might these individuals have developed the different principles governing the way each expressed his judgments about the length of the lines? (The answer to this question is a matter of interest in the traditional fields of both developmental and personality psychology.) The question is a special instance of the more general question, "How are different principles organized by individuals?" Control theory suggests the following explanation: Earlier in a person's life, some error signals could not be handled by the existing hierarchy (skills) of the person, and thus the hierarchy eventually was forced into reorganization. That is the nature of psychological development. During their skill-learning years, elementary and junior high school children ordinarily acquire many program-level systems, often simply because they are being taught to them. Eventually, conflicts between programs can result in stress and poor intrinsic-system regulation, so that the reorganization system is triggered, and a person begins the random regulation of conflicts between programs from which principle-level systems might develop. Since reorganization proceeds at random, whatever the course of action when control is reestablished tends to persist. A developing person might often formulate and reformulate tentative principles in attempting to generalize about what action really worked in a given situation. (Or, because intrinsic error decreased coincidentally with his or her action, as environmental conditions changed accidentally.)

It sometimes happens that a person copes with a given situation with random behavior on some occasion—stumbling into action bringing the environment under control momentarily, but without a principle being incorporated into the self-image. An example might be a person who escapes the consequences of causing a minor car accident by screaming hysterically, so that the other party decides it isn't worth it, and leaves the scene. The hysteria might have been triggered by a fear of getting hurt or killed, and perhaps additionally fueled by a thought such as "I'm already in debt, how can I handle this new expense?" That combination of error signals in existing systems could activate a wish such as "I wish I were not in this situation." If that "desired perception" was realized by the other party leaving, the tantrum would become a tool for controlling this kind of situation. (This kind of event would be called a *reinforcement* in traditional psychology.)

Whether or not the circuitry organized on that occasion would become a principle would depend upon its eventual place in the self-system. If the same kind of behavior is not followed by such "desirable" results on other occasions, it will not develop into a principle such as "Screaming is good for removing unwanted experiences." (Imagine some other person who had tried tantrums during childhood, but usually just got a spanking for his or her trouble.) Then, it would not persist, even though it worked accidentally on one occasion. It will not be "noticed" by the self-system if it doesn't work effectively on a number of occasions, and hence it will not be included in the self-image.

With the person for whom such "tantrums" frequently *were* followed by desirable events, such actions would ultimately evolve into a program for implementing a principle such as "Screaming is good for removing unwanted experiences."[1] Depending upon the actual form of that person's principle, his or her program in the future could include intentional screaming, which would be called a ploy, act, or manipulation.

Eventually a self-perception would be formed which contained the individual's own version of the above principle. Exactly what it might be, however, depends upon what other principles the self-system of that person would be regulating along with it. The following are various possible versions of the self-image in the above example: I (am a person who) can't control my emotions; I will do anything which works to get my way, including manipulating other people; I often get carried away and don't know what I'm doing, but that's me.

With this in mind, let us return to the relevance of Asch's experiments in demonstrating how the entire hierarchy is functioning in each task a person performs. Recall the facts he gave us. We interpreted his results as indicating that what his volunteers reported varied according to each one's own principle controlling "how to perform the task." For the person in whom the highest relevant principle was something like "I need to trust my own sense organs above all," the task was how to explain away the contradictory judgments of the others while holding onto what his or her own eyes told him or her. For the person in whom the highest principle was more like "It's essential to get along with other people," the task became one of "explaining" to oneself how it might be that his or her perception was distorted. And so on for the other variations.

A second source of variation in the results would have come from the volunteers' strategies for reporting their perceptions. But this activity would also be under the control of each individual's principles. For instance, some people apparently govern all of their action programs by a standard of perfection. Other people modify how careful they are in terms of how much value they put on the current activity. In like manner, the programs which any person develops in the "real world" are determined by what actually worked on previous occasions. Chance contributes a factor, because the random input of the reorganizing system can produce different actions which might work equally well. But only the one actually taken is preserved in memory, if the reorganization is retained.

Other programs in a person's hierarchy may either conflict with, or contribute to, the present action. The degree of skill of the lower systems affects what programs it is possible for a given person to develop at any given time. Finally, the exact nature of the environmental disturbances at the moment contribute to the resulting action. The particular action at the moment incorporates all of these influences.

Recall the experiment by Robertson and Glines (1985) mentioned in Chapter 10, in which the volunteers developed many different strategies for dealing with the task. We saw that the task varied for each person, just as in the case of Asch's experiment. For some, the task was "How can I escape from this commitment (as a research volunteer) as quickly and gracefully as possible?" For others, it was something like "What does he (the experimenter) really want me to do?" For still others, it was "What must I do to beat the computer at this game?" Thus, different individuals were doing quite different things, even though each was supposedly performing the same experiment. How each person perceived the task was doubtless affected by transitory conditions such as how much free time he or she had at the moment, by more long-run conditions such as other principles operating in that person, and by the programs the person already possessed.

Some subjects noticed that the problem was similar to others they already had learned to solve. This was especially true for physics and math students, for the problem was of a sort involving tactical control of time and relationship variables, which their education dealt with heavily. Other subjects brought erroneous previous experiences to bear, especially people who had experience with the kind of arcade computer games in which it is necessary to move fast with nothing much to be figured out. Although they tended to be enthusiastic about the task, many of these volunteers never solved it, because they locked themselves into strategies which didn't work. Still other subjects had no previous experience which seemed relevant to them, but they were interested in learning to win the game. They are the most interesting to us in this chapter, because they were the ones who had to reorganize a new program for solving this problem. Even they were not all in the same boat, however; some of them had different control systems below the level of programs which could be drawn upon in approaching the task. One subject, for example, commented that he finally hit upon the winning strategy because events were happening in a rhythm, and, being a musician, he began looking for a sequence of key presses to match the rhythm.

Granting all of the factors mentioned above, we finally come to the role of chance, or "trial and error." Little is known about this aspect of reorganization. In fact, since reorganization itself has not been a concept of traditional psychology, there is little in the way of previous research for interpretation by control theory. However, the theoretical, as well as the practical, implications of this concept for many human concerns are too important to disregard. If reorganization really does go on as if something were momentarily tossing dice within a person's central nervous system, sending neural signals at random, causing different muscle movements (hence, different actions), then even two clones would not necessarily bring a given perceptual variable under control at the same time, or in the same way. This observation could have important consequences in learning and training. It would imply that several people, all with supposedly the same intelligence, similar personalities, and essentially identical prior experience, could vary considerably in the time each would need to hit upon the proper moves to control some new situation. Efforts to achieve the right combination of conditions would be like flipping several coins until you got all heads. Hence, one could make serious mistakes in judging a given person's learning progress by comparing it with that of others with supposedly similar background and practice. (Or, perhaps even more importantly, one could misjudge one's own progress by comparing it with that of others.) Just by chance, one person might hit the exactly correct behavior pattern soon, while someone else with comparable ability might take much longer to hit upon the correct "readings" in all of the subsidiary systems simultaneously.

The above considerations are also important in clinical psychology and mental health, where comparison with peers has been found to be a big factor in self-esteem. A conception from social psychology, called "social comparison theory" (Festinger, 1954), expresses the view that in many human situations there are no objective measures of how well one is doing, and hence people judge their own competence by comparing their actions to those of others whom they consider pertinent. If one is playing golf, for example, the score is an objective measure for the question "Am I getting better?" But the question "How good a golfer am I?" only can be answered in reference to the question, "As compared with whom?" Assuming that social comparison is involved in organizing the self-concept, it can be seen that some people might judge themselves inappropriately harshly (or lightly) in comparison with others. If a person judges himself or herself without taking account of the chance-factor in reorganization, there could be a decrease in self-esteem as a result of comparing one's progress with that of someone who stumbles early upon an effective action. Thus, since self-esteem is considered a factor in mental health, social comparison judgments of one's competence can also become an issue in one's mental health (see Avia and Kanfer, 1980; Bandura, 1977; Brown and Inouye, 1978; Mahoney, 1979).

As we noted in Chapter 10, there is evidence that once principles involving negative self-esteem become included in the self-image, they can be activated if the individual starts behaving in *positive* ways. The self system could actually perceive desirable events as *un*desirable—as violations of a negative self-image—and "correct" them by activating principles which call for self-defeating action programs. This brings us to the subject of conflict within the learned hierarchy.

12.3 Conflict and Reorganization

Plooij (1987; Chapter 9 above) and Rijt-Plooij and Plooij (1986) reported very concrete descriptions of the variables controlled by the early actions of chimpanzee and human infants, showing that there is not a lot of variation in development of the lowest orders—even in different though related species—under normal conditions, and that increasingly complex controls develop in a definite order.

Things get more complicated as we move up to higher-order variables, however. Recall that higher-order systems must use the lower orders as their outputs. As the hierarchy gets more complex, it is inevitable that any given group of muscles get reference signals which are composites of several different higher-order output signals. The resulting action might not satisfy any one of the higher-order systems completely. Action would oscillate back and forth as error signals in one higher-level system or another kept resetting reference values to the program in action. Behavior of this kind has been described in traditional psychological theory as either "approach-approach," "avoidance-avoidance," or "approach-avoidance" behavior.

The fields of clinical psychology, psychiatry and mental health are devoted to the consequences of such conflicts. For instance, I (RJR) knew an obese person who said she wanted to lose weight. I believed this to be a sincere statement, and that she possessed a principle valuing thinness. She demonstrated the existence of this principle at various times in the past. However, she developed another principle, "I need to be my own boss," as a result of parental bullying during adolescence. When her weight became a desperate issue, she would employ an old habit of asking friends to remind her if they saw her overeating. But that resulted in an "avoidance-avoidance" conflict. If they honored her request, she would experience "domination," which she then would relieve by eating defiantly. If she realized she was doing that and stopped doing it, that would begin to reduce error signals in the principle valuing thinness, but then error signals would gradually increase in the second system until that principle (being her own boss) again demanded corrective action. Her weight, as well as her action, cycled back and forth.[2]

The above view was foreshadowed in two lines of investigation in traditional psychology of learning. Edward Tolman's (1949) concept of "vicarious trial and error" and the work on "experimental neurosis" by Pavlov (1937) and Liddell (1956) (discussed in Chapter 2, above) give us simplified examples of the working of conflict in animals. Tolman argued against the idea of behavior as a series of conditioned reflexes triggered mechanically by stimuli from the environment. He argued, instead, that behavior is devoted to the achievement of purposes which are selected within the organism. One of his experiments demonstrated what happens when purposes come into conflict in an organism. An animal was offered two paths for reaching a food box. On the first trials, before the animal knew whether or not one path was shorter, it might move toward one, then hesitate and move toward the other. It might do this a number of times before making a choice. Tolman called this oscillating action "vicarious trial and error" (VTE). It was vicarious, because the animal seemed to be testing the path "in its mind" instead of actually running both routes to compare them.

In certain of his other experiments, Tolman attempted to show that behavior functions to achieve a goal, rather than to execute a chain of conditioned moves, as argued in the conditioning theory of learning. In one, he trained rats to run through a maze to get to a food box in the conventional way, then he flooded the maze so that they could no longer use any learned "chain of reflexes." The rats had no problem in immediately swimming to the food box. Since they had never done that before, you could not say they had learned the chain of movements. Instead, he argued, they learned where the food was, and they used whatever actions they needed to reach their goal.

If we compare the above two kinds of studies by Tolman, we can make a distinction which clarifies the relationship of reorganization to behavioral variability or skill. In the VTE experiment, the animal would seem to have been caught between two reference signals conveying conflicting commands for the direction of movement. When it finally made a choice, that would indicate a regulation of the control systems which issued those commands by a still higher order. If the needed higher order *did not exist*, the resulting paralysis eventually would affect intrinsic control to the point of triggering reorganization, until a higher-order system developed to coordinate the conflicting programs. In the second experiment, there appeared to be no hesitation. The goal of getting to the food simply called up a swimming program instead of a running program. No reorganization was needed, because the necessary program of swimming was already in the learned hierarchy, and there was no conflict between higher orders as to what it should be used for.

In the experiments of Pavlov (1937) and Liddell (1956), we get a glimpse of what happens when reorganization is triggered, but then is prevented from completion. Even though they were not writing from the standpoint of control theory (and hence there were no clear tests for the controlled condition in their reports), we can surmise from a careful reading that the intrinsic system was probably affected, since the animals were forced to keep trying to solve problems which were insoluble for them. Both writers reported signs of intrinsic error: rapid heart beat, urination, defecation, screaming, struggling, and aggressive actions such as biting and jerking. The actions which once had been part of larger control systems for obtaining food now broke down into random acts aimed at escaping from the situation. But, since escape was prevented, the random actions continued to magnify, finally resulting in death under some conditions. The term "experimental neurosis," which Pavlov and Liddell used for the experiments referred to above, seems singularly appropriate, given the outcomes. We might wonder why psychologists in recent years seemingly have lost interest in drawing parallels with the increasingly frequent and sad reports in the daily news of the outcomes of various human stress conditions. We hope that better understanding of the processes of reorganization will contribute to renewed interest in the problem of the breakdown of control under extreme challenge.

Another relatively ancient study deserves mention in this connection. Masserman (1943) did a series of experiments with cats which, like the animals of Pavlov and Liddell, were gradually pushed to solve problems which they could not solve. He offered the cats a choice between plain milk and milk mixed with alcohol at the beginning of the training, and established that they refused the alcoholic milk. As the training progressed, and their ability to deal with the tasks began to fall apart, they began to prefer the alcoholic milk.

It is not difficult to detect the relevance of these early research programs to questions which are still of great interest in clinical psychology. What does the concept of reorganization have to contribute to a further understanding of the basic control processes which might be involved? Going back to the theory of reorganization, we note that, by definition, if an organism fails to bring a perceived condition under control, it will incur an error signal of steadily increasing magnitude in the system(s) involved. At this point, there are a limited number of options available to the organism: (1) a higher-order system (if one exists) can change the reference signal, effectively canceling the command, thereby removing the organism from the situation; (2) random action can succeed in organizing a new control system for the variable in question; (3) reorganization attempts can keep failing to bring the condition under control. In the third instance, as the organism continues with random actions, more and more conditions controlled by other systems will be interfered with and will develop error signals. There will then be increasing error signals spreading throughout the hierarchy, and increasingly widespread and intense random action to correct them. We believe that this is the condition called "panic" in some circumstances and "anxiety" in others. It is an extremely disagreeable experience, apparently not just for humans.

This would seem to be why people, as well as other animals, sometimes give up attempting to master certain situations after one or a few attempts. (Recall the research on "learned helplessness" in Chapter 11.) Under other circumstances, an organism might continue in the conflicted condition, using alcohol or other drugs to reduce awareness of the painful signals involved. This would also suggest why it might be worthwhile to tolerate the unpleasant feelings—in the hope that successful reorganization is imminent—as expressed in the "no gain without pain" exhortation of coaches, psychotherapists, remedial and rehabilitation trainers.

Notes

1. Remember that the statements with which we attempt to describe control systems are not what is recorded in a person's memory. For example, the statement "Screaming is a good way to get rid of undesirable conditions" describes a possible principle from an *external* observer's point of view. It is entirely possible that a person seen by others to have such a principle might not be aware of it, or might describe it to himself or herself in quite a different way.

2. Eventually, if other variables become involved and affect the intrinsic system of this person, it could trigger enough reorganization of her self-system for the problem to be solved.

Chapter 13

Social Psychology: Multi-System Control of the Environment

13.1 Introduction

The traditional field of social psychology is something of a hodgepodge. Different psychologists have seen it variously as the study of interactions between individuals, the influence of groups upon individual behavior and development, the processes of group formation and action, or the principles of communal/organizational behavior. Others organize the subject in terms of supposedly different, basic processes of social behavior, such as attitudes, social motives, social perceptions, social norms, interpersonal attraction, and affiliation. However, some anthropologists, and notably the American investigator of social class, Lloyd Warner (1952), view all social behavior—all forms of group action, as well as cooperation and competition between individuals—as expression of one basic principle: control over the environment.

Warners's view is congenial with the control-theory view that, in the long run, all action ultimately aims to maintain the necessary conditions for life of the organism and the species. In this sense, there is an unbroken chain of cause and effect from the most fundamental life-sustaining actions, such as breathing, to the most complex human social actions, such as fulfilling one's role in society. Complex control functions, such as cooperation, directly or indirectly improve the conditions of survival. In the course of evolution, those humans who cooperated in communities survived more often than those who lived alone.

This level of generality says nothing, of course, about any *specific* kinds of social behavior, attitudes, or values. But the postulate that social behavior, like all other behavior, serves the survival of the organism (and hence the species) helps to organze our thinking about social behavior. It suggests two specific questions about any social behavior of interest: What condition is kept under control by the action? Where does that fit in the control hierarchy of higher level systems?

To illustrate the above, let us refer to one of Lloyd Warner's analyses of large-scale social behavior—his hypothesis about the underlying purpose of Memorial Day parades, ending at the cemetery on the Memorial Day holiday. Warner (1953) offered extensive evidence for his view that the rituals of the celebration serve the purpose of bringing together community members of all social classes and walks of life in commemorating loved ones who died in war.[1] He claimed that the particular Memorial Day rituals carry largely unconscious, symbolic messages to the different classes of society that they, and their dead, had done the right thing in obeying the leaders of society by going to war. The main symbolic message is that the sacrifices shared by all had, in fact, preserved a "way of life" (read: customary and necessary conditions for living). The surviving members of the community and nation honor those from whose sacrifice they benefit. At the same time, there is the experience of community togetherness, enjoyment of the parades, ceremonies, and festivities, and the theme of "life goes on."

The rituals of other public celebrations carry corresponding symbolic messages regarding other aspects of the society's control over its environment. Without such periodic renewals of morale, Warner contended, people gradually would drift off into increasingly self-centered interests, to the point where they might hesitate or resist the orders of leaders in times of crisis. The potential dangers of such "social disorganization" could affect the conditions of living for everyone through the loss of resources in war or natural catastrophes, the destruction of food and shelter by waste or riot, and so on.

So, you might ask, what specific variables are controlled by the ceremonials of the Memorial Day observances? The answer Warner gave looks very much like a system concept: identity of the community and nation. The controlled perception, repeated at each level of social organization, appears to be a "self-image" of a group: family; parish; congregation; neighborhood; community; nation. Examples: "We are all Chicagoans," "We are all Americans." Sharing a common identity with others means recognizing common interests—sharing common principles or values which characterize the common identity. For example, "We will resist external forces which would change our way of life" is controlling a common principle, and must be implemented by *joint* programs of action. Some of the specific principles by which such common identity is maintained are patriotism, heroic sacrifice, "the good of the many outweighs the good of the one," and so forth. The action programs are the unifying actions of parading, pledging allegiance, flag waving, saluting, singing the national anthem, bowing heads in prayer, visiting graves, and hearing inspiring speeches in the company of fellow citizens. The action programs implementing other principles of the social system, such as holding elections, serving in the military, obeying laws in business and social dealings, and so on, accomplish other objectives for the system as a whole.

The other institutions of modern society—work, friendship, marriage, citizenship, club membership, charity work, and socialization of the young—may also be viewed in terms of mutual actions, or control of perceptual variables (at various levels) by multi-person control efforts. Those which have been investigated in traditional social psychology research studies can be arranged roughly in ascending order of the controlled variables in the control-system hierarchy. For example, beginning from the bottom:

Intensity: probably not separable as a controlled condition in social systems.

Sensation: there appear to be innate (genetically specified) touch-sensation reference signals in humans, as well as other primates. (Montague, 1986; Spitz, 1945)

Configuration: there also appear to be innate configuration reference signals, such as those involved in "imprinting" phenomena. (DeKasper and Fifer, 1980; Hall and Openheim, 1987; Ekman and Oster, 1979)

Transitions, Events, Relationships: the topics of perceptual-motor, skill-learning, and coordination research

Categories, Sequences, Programs: individuals must identify and match the movements of others in a broad range of activities, including avoiding bumping into others on the street, playing catch, anticipating where someone is going to steer his or her car, dancing, making love, etc.—studied under topics such as social cognition, person-perception, aggression, behavioral-matching, environmental psychology, and intimacy interaction.

Principles (personal policies, attitudes, and values): all of the generalizations, stereotypes, and favorable and unfavorable prejudices which we tend to see confirmed in the actions we perceive in those with whom we interact—studied under topics like person-perception, attribution theory, attitudes, value-theory, policy formation, social exchange, and equity theory.

System Concepts: the social entities which we perceive and for which we control perceptions, such as our own family, "our" organization, congregation, neighborhood, community, nation, and culture. We name social entities, such as married couples, friendship partners, and crony groups, and we identify the system concept which is involved with a common name (for example, a couple goes by a common name when they get married)—studied under topics like group psychology, organizational psychology, reference-group theory, relationship theory, and affiliation.

13.2 Affiliations (Close Relationships)

Next to the affiliation of mother and infant (often dealt with in textbooks on human development), the most basic and most profound human relationships are those of mate (or spouse) and friend. What kinds of perceptual variables are maintained under control in these interactions, how is it done, and to what reference settings do the variables tend to be stabilized? The interactions between the partners in these kinds of relationships are most commonly reported in the literature on "close relationships." Let us examine some of this literature.

13.2.1 What Is Controlled in Close Relationships?

Clark and Reis (1988) reviewed the recent literature on "interpersonal processes in close relationships," beginning with the definition by Kelley, et al. (1983) as "two people's behaviors, emotions, and thoughts [being] mutually and causally interconnected...." Clark and Reis asserted that their task was to "understand the nature of interdependence within pairs of people." They began with the concept of norms governing giving and accepting benefits. Investigators who have worked on the question of what people get out of being in close relationships have tended to report their results in terms of three main concepts, equity, equality, and need. Equity theory is the view that people try to achieve a maximum of rewards and a minimum of costs in any activity, including interacting with other people. In other cases, the partners want an equal distribution of benefits (equality), and in still other situations they want their individual needs met, even though it might seem very unequal, as when one partner prefers to dominate, and the other prefers being led.

In the course of each partner controlling the perceptual variable in which he or she is interested, the action each takes to maintain his or her perceptions in the desired condition may contribute to, interfere with, or simply parallel the efforts of the other. As Zimbardo and Ruch (1975) stated in their text on psychology, "When two people are involved in a friendship or romantic relationship, then *two* sets of rewards and costs need to be considered." Each partner must experience what he or she wants from the relationship, or it will dissolve. But this very fact then introduces a new type of controlled perception: the *relationship* as an entity, or controlled image, in itself. We shall consider this notion after first describing some of the earlier work on relationships.

13.2.2 What Do People Seek in Relationships?

What does a person want from a relationship? Can this question be answered for any particular relationship separately? Most psychologists have tried to find generalizations which would apply to everyone. Some simply have proposed that humans, like most other primates, have a tribal or "herd" instinct. To postulate that humans affiliate "because it's an instinct" does not explain the mechanism of the instinct; it proposes that no further explanation is needed: it's just the way we are. An attempt to find the underlying mechanism of affiliating has been made by some ethologists, who believe they have evidence that human infants become *imprinted* upon larger members of the species (their mothers, under normal conditions) early in life.

A brief description of imprinting, in control-theory terms, is that our genes carry a third-order reference signal of the outline of a human face, for which the infant controls in early direction of attention (Spitz and Wolf, 1946).

Other psychologists have proposed that we learn from an early age that being around others is rewarding, and that we thus develop a habit of needing to be in relationships. Pointing to the helplessness of the human infant, they argue that by the time an infant grows into a child, and begins to control events outside himself or herself, many reference signals have already been established for maintaining contacts with other people. The rewards are all of the various satisfactions of the control systems involved in eating, playing, learning, and working (see Thibaut and Kelley, 1959; Walster, et al., 1978; Huston and Levinger, 1978; Gergen, et al., 1980; Swann and Read, 1981; Bierhoff, et al., 1986; Tesser, 1987; Tesser, et al., 1988).

Some social psychologists have done research combining both of the above mentioned positions. For example, Stanley Schachter (1959) conducted the following experiment, attempting to demonstrate the "herd instinct" in humans. He divided his subjects into groups of which half were told they would receive painful electric shocks. This was to arouse "anxiety" in those who expected the shocks. The subjects then received a questionnaire asking whether they would prefer to spend the 10 minutes before the next part of the experiment alone or in the company of another subject. More subjects expecting shock said they would prefer to be with someone else than did those who did not expect to be shocked. Schachter's interpretation of his results began with the assumption of an instinct for affiliation among humans, and he believed he found that it increased when a person began to be anxious. However, that would still leave the question of *why* the need increases when a person becomes anxious.

A different way of interpreting Schachter's (1959) results is that some subjects —as usual, his research method drew conclusions about individuals from group averages—*feared* the shocks, and they became "anxious" because of not knowing how to act in the situation. At least some of them then would want to compare notes with others, in hopes of reducing the error signals in their own higher-order systems.

Notice, however, that even though Schachter's research was intended to show that people want to join together when under stress, it does not tell us directly what they got out of it. His subjects were strangers; they did not have previous relationships. What he actually found was that (a majority of) those threatened with shocks wrote on a questionnaire that they would prefer to wait with someone else, while a majority of those not threatened wrote that they would prefer to wait alone. There was no actual evidence that they would have done what they claimed, if given the chance. However, as we suggested above, Schachter's results do indirectly point to an activity which people might seek in relationships with others, in pairs and larger groups. That is the opportunity to compare notes, or, in other words, to get suggestions as to what to do—what perceptual condition to try to control in an unfamiliar situation.

Thus, "social comparison" is one among many different motives, gains, objectives, or functions served in close relationships. Others are the satisfaction of personal physical and social needs by a partner, satisfaction of skill-learning and playing activities which require a partner or co-participants, and finally the self-defining and self-discovering activities occurring in intimate communications (Berscheid, 1985; Berscheid, 1986; Berscheid and Walster, 1978; Hansson, et al., 1984; Kelley, 1986).

13.2.3 What Attracts People to Each Other?

What attracts a person toward another for possibly forming a close relationship? Newcomb (1956) did a pioneering study of this with college students, providing housing in return for which they provided answers to frequent questionnaires about themselves and the formation and conduct of close relationships among them. One of his major conclusions was that just about the only pre-acquaintance measure for predicting who would later be close with whom was the number of non-person objects about which the (future) friends held similar attitudes. None of the various hypotheses about what attracts people to each other —similarity or complementarity of personality type, similarity of attitudes or values, or complementarity of emotional needs—could be confirmed by his measures in that study.

I (RJR) did my dissertation project on a related issue: whether people with similarities in their personalities tend to choose each other as friends or mates, or, conversely, whether people develop such similarities after becoming friends or spouses (Robertson, 1960). Like Newcomb, I found that—among a group of 40 junior executives who were brought together for a two-month training program—those who eventually paired off as friends were originally no more like each other than any of the others in the program. They did not average higher correlations with each other on measures of personal attitudes and values (gathered before they met) than the average correlations within the group as a whole. I did find friend-pairs to have somewhat higher correlations (on the average) than the group as a whole at the end of the training program. I took this as evidence that the friends were tending to become more alike *as a result* of their interactions.[2] But the question of why they became friends in the first place remained unclear, as it did in Newcomb's larger study.

Broad sociological measures, such as availability through propinquity (nearness) and similarity in social status, are mild statistical predictors for who will affiliate with whom, both in spouse and friendship relationships. But specific pairings seem to result from many different intentions of those involved, and no attempt to formulate a generalization true of everyone has proven successful.

13.2.4 Hypotheses Regarding Controlled Perceptions in Affiliations

Here is an example of a different type of generalization about relationships, derived from Powers' model of the human organism as a control system; if true, it should be true for everyone. Close relationships show features like those of control systems. That is: (1) close relationships have a system concept, or identity (a "we"-ness) which is protected against disturbances; (2) that identity will be referred to when principles (policies, values, attitudes) come into conflict and must be resolved; (3) the implementation of the principles requires specific programs of action; (4) which are developed as the relationship is growing; (5) and in fact, constitute much of the activity of the early growth of the relationship; (6) analogues for several of the types of controlled perceptions below the level of programs will also be found in such multi-person "systems."

A corollary of (6) is that the general scheme of a hierarchical control system would be useful for examining human organizations of other sorts besides two-person relationships. There is some debate among control-theory psychologists as to whether to consider human organizations as control systems, or simply as organizations which function similarly to control systems. The parts of a true control system are hooked up in a physical sense. Therefore, societies, corporations, families, and the like are not true control systems. Nevertheless, concepts such as the "social system," the "family system," and the "corporate system" are already familiar in common parlance. Since it appears that these concepts will continue to be employed, it seems a good idea to describe them in terms conforming to an accurate picture of how control systems work. Let us consider them technically as "quasi-control systems."

13.3 Control-System Hierarchies in Multi-Individual "Systems"

We have discussed the concept of the self system as the highest control system in the individual, along with its implications and some of the research interpreted by this view, in previous chapters. What do we find when we look for an analogue of the system concept in couples, cliques, families, clubs, congregations, communities, and societies?

Recall the basic feature of any control system: it maintains its controlled variable constant (matched to its reference signal) against external interference. Thus, to employ the test for the controlled condition—to see whether a group's or a couple's system concept resists external disturbance—we must first define what it is controlling. I propose that it would be the identity or "image" of the "system." Next, I speculate as to what might constitute external disturbances to such variables. I propose that it is any type of "insult" or challenge which states or implies that the group doesn't exist, or isn't what it defines itself to be.

We are going to look for evidence that the definition of a group identity or self-image is protected against disturbance (that is, distortion or misperception) in groups of different sizes, from friend and spouse pairs to communities and national groups. However, since this never has been studied previously as a phenomenon within the control-theory paradigm, we might have to look for indirect evidence within traditional studies of interpersonal and intergroup relationships. It may be that much of the testing of this hypothesis remains for a new generation of psychologists.

Would the U.S. Civil War be an instance of the preservation of a group identity against an attempt to alter it? There have been many reasons attributed to the War: economic, ideological, and social. However, the first "insult" to the concept of "The United States of America" was the definition of another identity, "The Confederate States of America." One way to look at the specific happenings of the Civil War is to see them as implied by the proposition that the highest level in a control hierarchy, the concept of the system, acts to preserve the definition of the system. In the hierarchy we have presented in this book, the system-concept control system operates by sending reference signal values to principles under its command. In the case of the Civil War, the particular principle on which it began was "You can't secede."

This way of looking at group behavior brings us back to the work of Lloyd Warner, with which we began this chapter, notably his studies of the identity-confirming function of symbolic ceremonies in nations, communities, and organizations.

Another place in which to attempt to apply multi-person systems analysis would seem to be research on the efforts which members of ethnic groups take to preserve their group identities, and research on the efforts which married couples and friendship pairs take to preserve their pair identities.

If large and small groups do act to preserve their self-definitions, identities, or self-images, do the entities in question show other outputs beside actions to preserve the common identity? Here we come to the subjects of conformity, attitudes, decision making and leadership. Each of these topics is a major category or subdivision of the field of social psychology.

13.4 Control of Principles in Multi-Person "Systems": Attitudes, Conformity, Social Roles, Leadership

13.4.1 Research on Attitudes

Attitudes usually are defined by psychologists as tendencies to evaluate or react to specific social "targets"—groups or categories of individuals—in the same way over time. One whole class of attitudes involves stereotypes or prejudices. Another major class of attitudes involves values—valuing certain customs or objects over others. For example, Americans generally place a negative value on dogs as food, while some Asians place a positive value on them as food.

The study of attitudes has long been one of the most intensely explored subjects in social psychology. We shall examine a few representative examples here, and then consider how the findings about attitudes might fit into a picture of them as principles in a control hierarchy. In that light, they should determine what course action programs should take in specific circumstances, going down the hierarchy, and to preserve the system concept, going up the hierarchy.

A famous study of attitudes was done by Theodore Newcomb (1958) with women at Bennington College. He lumped values toward specific subjects into two broad categories: liberal and conservative. His subjects were young women from mostly wealthy and conservative homes. Their teachers at the college were mostly liberal. In a study which lasted over several years, he found that most students' values became more liberal the longer they were at college. He also found that individual students with higher status or prestige among their fellow students tended to be more liberal, while students who remained conservative tended to be less valued by their fellow students.

Let us examine these findings to see how they might fit the concept of a controlled principle. Suppose a student in Newcomb's study had in her self-image a perception which we might state in words such as "I am one of the superior people." How was "superior" defined in that environment? As being liberal. Then how did one maintain the system concept of being superior? Among other things, by having liberal principles. How do we recognize principles? By inferring from a person's actions what values are being implemented by his or her actions. Thus, a senior whose tuition in college was paid by a father who owned a factory employing strike breakers might answer an attitude questionnaire asking "Should there be laws banning the hiring of strike breakers?" with "Yes." As a freshman, she might have answered the same question with "No." While executing her "questionnaire-answering program," she would have been implementing a principle preserving the liberal self-concept developed through interactions with her professors and peers. The thought of where her tuition came from might well not have entered her mind at that moment, because it did not pertain to the variables controlled by questionnaire-answering. (Of course, calling her attention to the subject of tuition just then might create the "cognitive dissonance" defined by Festinger, as discussed above in Chapter 10.)

The above example reflects many of the broad topics of interest pursued by various researchers on the subject of "attitudes." For instance, the questions of why peoples' actions and attitudes are not always in agreement and how attitudes develop and change, and the problems of measuring attitudes accurately.

13.4.2 Group Conformity

As we examine the above material further, we can view it from two different perspectives. One is the control of a person's perceptions of his or her place in a group; the other is the control of a "system" concept, or identity, by joint actions within the group as a whole. We have just examined the first half of the picture. Notice how Newcomb's research compares with the group-influence research of Asch, discussed in Chapter 11. Asch (1951) was looking at what his subjects did. He did not focus on why they did it. Newcomb's focus was just the opposite; he explained the way in which his subjects answered attitude questionnaires in terms of their being liberal or conservative. From our point of view, we can explain the behavior of the subjects of both studies in terms of the particular self concepts and principles which the subjects' actions were implementing.

Now let us look at the material from the other side—from the perspective of the members of the groups studied. Why did Newcomb's and Ash's subjects care what their peers did? Why do people in general seem to care what their peers do? The question seems easy to answer when one person's actions have material consequences for others. But that would not seem to apply in either Newcomb's or Asch's experiments. Questions of this sort pertain to the traditional social psychology subtopic of social conformity.

Newcomb drew upon the concept of "reference group" in describing the change of attitude from conservative to liberal by the majority of his subjects. A reference group is defined as the source of standards to which one refers in choosing what to value. If you recall the concept of the "social comparison process," the point was that people tend to choose their reference levels for symbolic or abstract actions by seeing what others generally do in similar circumstances. A person's reference group is defined as the most relevant source for the social comparison, because one wants to act like those with whom one identifies, not just anyone.

With whom do people identify? This comes full circle back to the topic with which we began this chapter. People tend to see themselves as parts of larger wholes: families, peer groups, ethnic groups, religious denominations, communities, social classes, nations. A person can have a system concept for *each* of those "systems": oneself, or any of one's groups. The system concept equals, or includes, an identity, which becomes a controlled perception once it is defined. For example, if we are both members of a group having an identity including (let's say) an image as "enlightened liberals," and I perceive you acting in an "illiberal" way, it disturbs my perception, and I get an error signal. My perception of the attributes of the group image is distorted, and I automatically begin corrective action; I might scold, censure, or criticize you, trying to get my error signal reduced. If none of that works, I might go on to try to kick you out of my group.

Since a system concept is such a high-level variable, there are many different corrective actions possible. It is not hard to identify the corrective actions as implementing different principles: "Don't disgrace the group"; "That's not what we stand for"; "Remember who we are." If none of these corrective actions succeeds in reducing the disturbance of the group image, other principles are called upon: "You're a heretic, a traitor, a rebel. Return to right thinking, or be excommunicated."

The theory proposed here is that there is a link between the individual's perceptions of himself or herself as an individual and himself or herself as part of some larger "system." The system concept, or self-image, of each such "system" is a controlled perception for the organism(s) involved in it. Thus, group conformity can be seen as an implication of the way control systems function.

Another psychologist, Stanley Milgram (1977, 1965, 1964), is noted for his series of disturbing studies of conformity to authority. His description of the origin of this work places it within the context of the present discussion. It is interesting enough to deserve reporting his story in some detail.

> I was working for Asch in... 1959-60 [and] thinking about his group pressure experiment.... Could a group, I asked myself, induce a person to act with severity against another person? ... I envisioned a situation very much like Asch's experiment in which there would be a number of confederates and one naive subject [but] the question would be to what degree an individual would follow along with the group [but, in looking for an experimental control, I transformed it into a study of] Just how far will a person go when an experimenter tells him to give increasingly severe shocks [to another experimental volunteer].... I would like to call what happens to Asch's subjects "conformity," and I would like to call what happens in my experiment "obedience." ... in Asch's experiment, you're dealing basically with a process of which the end product is the homogenization of behavior.... Obedience arises out of differentiation of social structure... one person [has] a higher status. (Milgram, 1977, pp. 94-96)

The actual experiment consisted of telling a research volunteer that it was a study to find out what effects punishment has upon memory in learning. The subject was led to think that he had drawn the role of "teacher"—giving increasing (simulated) electric shocks to another volunteer (really a stooge of the experimenter) who played the role of "learner." The stooge began to exhibit signs of increasing pain as the experiment continued, while the researcher kept urging the "teacher" (subject) to disregard the indications of torture and keep raising the (supposed) shock level.

Milgram repeated this procedure with many different groups of subjects, and, like Asch, he found that some persons would obediently follow the instructions, despite their belief that they possibly were killing the other "subject." Other people drew the line, some sooner, some later. Where the line was drawn varied under conditions of varying "immediacy." The least immediacy consisted of the subject only hearing someone hit the wall in an adjoining room, and the most immediacy consisted of the subject being told by the experimenter to press the "victim's" hand down on the metal shock plate.

The report of Milgram's findings created a great stir, as many readers took them as indications that a good many Americans would be highly susceptible to fascistic dictatorships. Others criticized the deceptive aspects of the research, or the moral implications of convincing people that they might easily become torturers.

From a control-theory standpoint, we can see that the variations in Milgram's experimental conditions held possibilities for large differences in the perceptions controlled by the subjects. That would mean different principles in different subjects. In the most remote condition, more of the subjects would likely be controlling their relation to the experimenter with only a small input from the "victim," while in the most immediate condition, the balance would be shifted in the opposite direction. Thus, the interpretation of the results would be problematical.

Do they really indicate that many people would heartlessly torture fellow-citizens when told to do so? Looking at the backstabbing actions of frightened people in totalitarian dictatorships while purges are going on, we might well be prepared to believe that. However, our proneness to believe it still doesn't answer the question "Why?" To do that, we need much more research upon what the actual controlled variables are for each of the subjects in experiments such as those of Milgram. We might find that there is a very large number of different controlled conditions being rolled into one conclusion.

13.4.3 Social Roles and Group Leadership

Consider another disturbing set of findings, of Zimbardo, et al. (1973), which overlap those of Milgram in certain respects. Students enlisted to play roles of guard and prisoner in a mock prison experiment were soon enacting their respective roles with deadly seriousness. We would interpret the findings in terms of the fact that the same program-level variables are controlled by principles for *acting like* a guard as would be controlled by principles involved in *being* a guard.

The common denominator in the above mentioned studies is that individuals control the variables in a social system by controlling those of their own perceptual variables which are determined by their position within the system. Thus, in the observations reported by Zimbardo, the "guards" would be able only to carry out their roles with whatever lower-order systems existed in their repertoires. It does not seem surprising that untrained (as guards) college students would be inclined to behave about the same way as most poorly trained real guards do.

Turning now to the topic of leadership, or setting of the reference signals directing the actions within human groups and organizations: whether or not humans have some kind of instinctual "motive" for combining in tribal groups (a reasonable hypothesis in terms of anthropological studies of primitive societies), it is logical that the more levels which develop in a control hierarchy, the more varied must lower-order repertoires be to implement them. That is an abstract way of saying that specialization becomes an advantage as group size increases, since not everyone can do everything equally well. One can observe that even fairly young children perceive this on the playground. All it requires is to see each other in action. It then soon becomes apparent that some can do certain things better, while others can do other things better.

As individuals begin to form group system concepts, one of the specializations which develop is the specialization of seeing the "social system" from the point of view of its principles. By the definition of the concept of control systems which we are employing here, the individual who perceives the maintenance of the group's principles *as if they were his or her own* is viewing them from above. That is, he or she is viewing them from the position of controlling the system concept of the group as a whole. That is exerting *leadership*, as he or she acts automatically to reduce errors affecting the preservation of the system concept, or identity, of the social "organism."

This was illustrated by a study by Cartwright and Robertson (1961), in which it was found that, in several small workshop peer groups, the members coalesced around leaders whose individual values for achievement most resembled the average in his group. That is, groups in which achievement tended to be highly valued (on the average) were led by leaders who valued achievement highly, and groups in which achievement tended not to be valued so highly were led by leaders who did not personally value achievement so much. In each group, the leader was the person who most closely identified with the central value position of the group as a whole.

In conclusion, we should point out the impossibility of describing even a large portion of the number of interesting studies which have been done in the various topics of social psychology. We invite readers with a special interest in any of these topics to pursue them further in the literature. However, we suggest that it will help to reduce the many seemingly different phenomena described there to a manageable organization, by translating the findings in one's own mind into control-theory terms, as we have attempted to illustrate above.

Notes

1. Though seemingly with less committment than at the time he wrote, 40 years ago.

2. This study was done before I learned of control-theory psychology. At that time, I followed the conventional practice of drawing conclusions about "all" individuals from the averages taken in measures on groups.

Foreword to Part 5

The new orientation to the study of psychology which the control-theory model facilitates has consequences in new questions to investigate, new ways of conducting research, and new solutions to human problems. Here, we offer some preliminary glimpses of several implications of the model, in hopes that future psychologists will contribute to expanding this material.

Part 5

Applications and New Directions in Psychology

Chapter 14

Clinical Psychology from a Control-Theory Perspective

14.1 Introduction

Clinical psychology is a subfield of applied psychology in which the psychologist applies the facts, theories, and methods of psychology to the goal of helping people solve personal problems. Clinical psychologists engage in two major kinds of activities, psychological testing and psychotherapy. Clinical psychologists currently do not prescribe drugs. For those instances where drugs might be helpful, clinical psychologists work with consulting psychiatrists or other physicians.

In this chapter I (DMG) shall describe applications derived from control theory as I use them in my work as a clinical psychologist. They help to show how this new model is beginning to contribute to the clinical field of applied psychology.

The first such contribution is the possibility of bringing about a unified approach to assessment and treatment. This means that the same set of concepts forms the basis of assessment and treatment methods. This makes it easier for the clinician to translate the results of psychological testing into diagnostic and treatment suggestions. A second benefit is that the clinician can measure therapy progress in the same terms as the initial assessment.

14.1.1 Brief Review of Control Theory Concepts

The terms printed in italics are the basic concepts of control theory which I shall use in this presentation. A person checks perceptions (*perceptual signals, p*) against his or her reference value for the perception in question (*reference signal, r*). As an example, imagine a person driving a car. He or she compares (automatically, unconsciously) what he or she is sensing against what he or she should be sensing. One typical driving goal might be: Am I safe? The goodness of fit between the current perception, *p*, and the reference perception, *r*, determines the size and direction of the momentary error condition (*error signal, r-p*). *Error signals* can vary from zero (perfect match) to some large (positive or negative) number. The person's brain functions to keep *error signals* as small as possible.

Continuing with the above example, if the driver perceives that the car ahead has stopped suddenly, this creates an *error signal* with respect to the goal of driving safely. When there are no *error signals* related to a given perception, actions related to this perception do not change. When there is a non-zero *error signal*, actions do change to bring about a correction. *Error signals* in the control system for driving safely result in corrective actions such as turning the wheel, sounding the horn, or stepping on the brake. (Which action it will be is determined by the particular subsystem in which the current error exists.)

As *error signals* are being corrected, there are physiological and biochemical changes in body state accompanying the actions. Actions cause changes in the physical environment which, in turn, alter perceptions. Thus, an *error signal* in the control system for safe driving also would involve arousal in the body. In this case, the person might experience surprise and/or fear.

Perceptions are always combinations of the effects of the interaction between current action and environmental factors. The person-independent influences are *disturbances*. The sudden stopping of the car in front is the *disturbance* in the driving example.

Adequate control of perceptions having to do with everyday life is what everyone wants. Adequate control in the example of driving means: (1) Perceptions will be matching reference values ($p = r$). The person is achieving his or her goals —he or she perceives himself or herself driving safely. (2) The perceptual impact of actions (feedback) will be exactly equal and opposite to the impact of disturbances. The person maintains goals in spite of changes in the physical environment. He or she adjusts actions to keep perceiving "driving safely," no matter how conditions change.

Sometimes people have chronic error signals resulting from conflicts between competing goals (two different and incompatible reference values for the same perception). In the driving example, the person may want to drive fast in order to reach his or her destination on time. On the other hand, he or she may want to drive slowly in order to be safe. The car cannot be driven fast *and* slowly. If chronic error signals continue, the person's inborn reorganization system will go into action. When this starts, the control systems which were in chronic error change randomly, by trial and error. For example, a person driving a car is confronted with a novel situation, if he or she is an American driving a car in Great Britain. This requires some reorganization of driving control systems. Recall from Chapter 7 that many other systems may register error signals as their current perceptions are disturbed by the effects of the random trial and error of reorganization. The spread of error signals can at times be like a whirlwind, resulting in the conditions called anxiety, or, even more severe, panic. Reorganization ends when the error signals in the inborn (life-support) control systems reduce to zero. (Whether the new action is beneficial to the organism, or changes in external circumstances accidentally let the intrinsic system recover normal functioning, reorganization halts, and the new organization persists until reorganization again is turned on.)

Since, however, many persons do not have a conception of reorganization as random attempts to resolve conflicts within their hierarchy of control systems (and perhaps even if one does), one's awareness may be so focused upon the discomfort of the *symptoms* of reorganization as to be unable to identify the inner sources of conflict. In such circumstances, clinical psychologists employ various diagnostic procedures to aid in uncovering the inner workings, of which the victim, client, or patient is not aware. A major part of the clinician's armamentarium for this purpose consists of psychological tests.

14.2 Psychological Testing

Before a clinician can help a person solve a psychological problem, he or she must have a good understanding of what the problem is, and who the person is who has the problem. Psychological tests can help gain this information.

In the past, it was common to create psychological tests not based on theory. This practice is still the rule among psychologists who apply behavior modification techniques. "Target behaviors" are chosen, based on practical considerations. For example, if a child refuses to do what others want him or her to do, and if this is judged to be problem behavior by significant others, many behaviorist psychologists would have parents and teachers count the number of times this "noncompliant" behavior occurs. The count of this behavior becomes a psychological test of the child's "noncompliance." The efforts of the psychologist would then be directed at finding out how to influence the child to change the noncompliant behaviors.

Today, however, creation of psychological tests is increasingly being based on theory. Theory suggests what is important to measure. A test which gives consistent results is said to be a reliable test. Theory also indicates what relationships to expect between the test and other tests. A test which relates to other tests as expected by the theory is said to be a valid test.

There are ability and personality tests. A classical ability test which you might have heard about is the IQ test. A classical personality test is the Rorschach inkblot test. By way of analogy to a computer, an ability test can be thought of as a measure of performance related to a "hardware" feature of a person. A personality test is a measure of performance related to a "software" feature of a person. Within control theory, the "hardware" features are the control-system hierarchy (perceptual levels) and the reorganization system. The "software" features are the specific control systems which a person acquires.

I shall describe some preliminary applications of control theory in the development of new tests. My discussion is limited to control-theory-based test development, but it will provide a view of psychological testing in general. The interested reader can learn more on this topic from the following books: Rotter (1966) provides an introductory discussion of the standard tests; Vane & Guarnaccia (1989) provide a recent review of the clinical utility of the standard personality tests; and Comrey (1988) provides a tutorial on the methodology of constructing personality tests.

14.2.1 *Ability Tests*

The levels of perceptions could be the basis for some novel ability tests. It would be helpful to clinicians to have a measure of how well a person can control perceptions at each level. A possible test might consist of giving a person an opportunity to control a perception at a given level, then measuring how well the person controls disturbances. The model of the hierarchy presented in Chapter 5, depicting 11 levels of different perceptual abilities, contains the postulate that the perceptual abilities are not independent of one another. The relationship between the perceptual variables of any two adjacent levels is that of superordinate to subordinate.

Powers (1978) has suggested that a statistic called the *stability number* can serve as a measure of how well a person is controlling a perception. How it works can be illustrated by a type of ability test—a task of tracking a target on a computer screen—which Powers developed. Imagine that you are sitting in front of a computer monitor with a game paddle in your hands. On the screen is a target line. It might be of a given color, or a display like this: —— ——. The computer moves this target line up and down on the screen in a smooth but unpredictable way. You can use the game paddle to move a second line of a different color or style up and down. The line you control might look like this: ****. The task is to align your line with the target line so the result always looks like this: ----****----. This requires the ability to control the relationship between the two portions of the line. The amount of discrepancy (like ___****___), or error signal, can be measured by the computer, and a ratio from which the stability number is obtained can be calculated by dividing the actual off-target variability (variance) by the expected variability (variance). ("Expected" if the disturbance effects and the effects of the subject's actions were unrelated.) This ratio is 1 when a person is completely unable to perform the task, and it grows progressively larger as a person's performance improves. The square root of this ratio is subtracted from 1 to calculate the stability number. Thus, a stability number of 0 means zero control. As the stability number falls, the control of the perception is increasing. Hence, the stability number measures how well a person can perform the task, from no control at all (the performance of a person not turning the paddle) to increasingly better control. It is a function of data from the individual person, and is representative of that person, just as is one's own blood pressure reading.

This approach to performance description is very different from most current ability tests. Performance in standard ability tests typically is measured with reference to group statistics. The statistics compare how well the person did relative to the performance of others who took the test. For example, an IQ score is a standardized score. An IQ of 100 means that the person performed the same as the average person of the same age. An IQ greater than 100 refers to above average performance. An IQ less than 100 refers to below average performance. Thus, the description of a person's performance is dependent on the group of people who have taken the test before (norms). If the so-called norms are changed, the performance description changes.

Performance in the pursuit tracking task has a clear conceptual meaning. It provides information on a person's ability to control a relationship-perception. Can this test be applied to any practical concerns? Goldstein and Sabatina-Middleman (1984) used the pursuit tracking task with a group of special education children. We found that performance on this task appears to measure a separate dimension. It was not correlated with IQ, attentiveness in the classroom, or behavioral problems at home. Goldstein, Powers, and Saunders (1987), using the pursuit tracking task with a number of adults, found that it tended to be somewhat correlated with hypnotic ability.[1]

14.2.2 Personality Tests

Robertson, Goldstein, Mermel, and Musgrave (1987) developed an experimental procedure to investigate the hypothesis that the self concept (or self-image) is a perceptual variable regulated by a control system at the system level of perception. If the hypothesis were true, elements of the self-image would be maintained at particular reference values (presumably by the self-control system; see Chapter 11). The data showed that individuals opposed disturbances of the self-image traits, as predicted by control theory. Unlike the typical personality study, the action of correcting the disturbance was reported for almost all subjects.

I have found this conception of the self as a control system of use in clinical practice. I developed the following procedure to obtain the self-image. I give a person these instructions: "Imagine that your life will become a movie. Imagine that you are talking to the person who will be playing you. Give the person instructions on how to be you. Let your statements take the form: Be______. Don't be ______. What kinds of instructions would you give? Be as complete as you can in the instructions given." I give my client as much help as necessary to generate a set of statements. Most people generate some instructions in a little while.

Once a person has created a set of statements, the next step is to find out which aspects of the self-description are controlled perceptions, by attempting to disturb his or her maintenance of them. (Traits or attributes which a person assigns to his or her self-image, but does not correct when disturbed—contradicted—by another person, are not controlled perceptions. They could be thought of as "window dressing," or what is technically called "social desirability rating" in traditional personality research.) Disturbing the self-image can be done by questions, interpretive statements, paraphrases (especially if slightly off-target), and body language gestures by the therapist which might suggest some skepticism or doubt. Negative emotions, body stress, and verbal/motor actions are to be expected as the person counteracts disturbed controlled perceptions. It is important to vary the approach taken and not test the control of the self-image too severely. Otherwise, the patient may start to perceive the therapist negatively.

Some people cannot produce a self-description during a therapy session, for reasons which are not presently clear. A possible explanation for some people might be that they lack awareness of their self-image. Fenigstein, Scheier, and Buss (1975) developed a personality test of self-consciousness to test that hypothesis. In their measure, an individual rates each of 23 statements for how much it is like or unlike himself or herself. Higher scores indicate greater awareness of one's own psychological states than do lower scores. The researchers concluded that a person had to be aware of his or her self concept in order for it to show influence on behavior. Thus, the behavior called self-description would be one kind of action which is difficult for such people. Carver and Scheier (1981) used this test and also concluded that individual differences in self-consciousness tend (on the average) to be correlated with the extent one's actions will be affected by his or her self-image. They also asserted that steps to increase a person's self-consciousness intrapersonally tend to be followed (on the average) by actions showing increased conformity to self-image.[2]

People who lack awareness of their self-concept (or image) might do so because they function at lower levels of perception. Recall that Robertson, et al. (1987) hypothesized that the self-control system, at the highest level, controls perceptions of the self-image. Vallacher and Wegner (1985) reported a personality test which measures the characteristic level of perception from which a person functions. Their test, the Behavior Identification Form (BIF), consists of 25 questions of the following type: "What does tooth brushing mean to you—(a) preventing tooth decay or (b) moving a brush around in one's mouth?" The former choice is at a higher level, while the latter choice is at a lower level. These authors went on to show that higher BIF scorers tend to describe their self-concepts in more abstract terms. Higher BIF scorers (on the average) believe that they have more control over their lives, tend to be less anxious, and are less sensitive about other people's comments.

The Behavior Identification Form uses a testing format called forced choice. The subject is forced to choose one of the two alternatives; no other choices are allowed. Objective personality tests frequently employ this format. An alternative approach is to ask a question and allow the person to give whatever answer he or she wants. The person's response can be judged in terms of the 11 levels of perception. The "(a)" choice in the illustration of the preceding paragraph is at a principle level of perception. The "(b)" choice is at a relationship or sequence level of perception.

The Myers-Briggs Type Indicator (1985) is an objective personality test which uses four personality traits to classify persons into one of 16 possible types. The second of the four traits is called "sensing versus intuitive." The person with a "sensing" perceiving preference is described by Hirsh & Kummerow (1989, p.36) in the following terms: he or she predominates in using the five senses (vs. the "sixth sense," hunches); what is real (vs. what could be); practical (vs. theoretical); present orientation (vs. future possibilities); facts (vs. insights); preferring established skills (vs. learning new skills); utility- (vs. newness-) mindedness; step-by-step (vs. leaping around). (Obviously, such generalities apply to an imaginary "composite" person, typifying the category more fully than any single real person given this classification.) The person classified as "sensing" would seem to prefer to perceive in terms of lower levels of perception. The person with an intuitive preference would seem to perceive in terms of higher levels of perception. Thus, the sensing/intuitive trait polarity can be interpreted in control-theory terms as corresponding to the idea of lower and higher levels of perception.

Q Methodology (Brown, 1980) is an approach to personality testing which survives many of the control-theory objections to the standard personality tests. The selection of test items can be individualized for the person and issue being studied. The subject sorts the items according to instructions which also can be individualized.[3] The main emphasis of the method is to study the perceptions of the individual person. These features of Q Methodology make it a promising avenue for control theorists to explore.

Goldstein (1987) applied Q Methodology to study the perceptions of clients in therapy. In the case of one individual, three classes of people were identified among his significant others: (1) ideal people (accepting, sociable, and not aggressive); (2) people in his immediate family (aggressive, not submissive); (3) people like himself (depressed, not assertive). He had, as a presenting problem, the fear of talking in front of people at work. He related the people at work to type (2) people, with whom he had associated fear reactions. Another issue was his relationship with a girlfriend, who was a type (1) person, while he described himself (via the Q sort instrument) as a type (3) person. There seemed to be an implication that he did not feel good enough for his girlfriend. His ex-wife was described as a type (1) person.

14.2.3 Practical Considerations in Testing

Now I shall describe how I use standard psychological tests, along with those described above, within a control-theory approach. The basic concepts of control theory provide a working model of a person. Standard psychological tests provide some information which can be used in various aspects of this working model. I shall organize this report using the following outline:

Perceptions
Reference Perceptions (Reference Values)
Error Conditions
Actions
Disturbances

Then I shall formulate treatment recommendations based upon the data I cite in each of the above categories. (An example of my record form is given at the end of this chapter.)

Under each of the control-theory headings in this report, I include the following kinds of information. I give my client a definition of the term which makes up the heading. I follow this by a description of the general kinds of problems which therapists encounter, related to that term. (See the following discussion on treatment for a description of the kinds of problems involved in each heading term.) Then I indicate for each of the general kinds of problems whether it applies to the person being tested. Finally, I summarize the specific test results which support or do not support the judgments I have made.[4]

14.3 Psychological Treatment

The evaluation methods discussed in the prior section provide limited information regarding how treatment should progress. Control theory encourages the clinician to seek the the answer to two questions: What perceptions are out of control? What aspects of each control system need change? In practice, the therapy sessions themselves become the means to assess as well as treat. I see my job as therapist as helping the individual regain control over his or her significant perceptions. People who come into therapy usually are in some kind of crisis in life and are experiencing significant stress as a result.

I developed the Life Perception Survey (LPS) and Life Perception Profile (LPP) (Goldstein, 1988) to assess and monitor progress in psychotherapy. The reader is invited to complete the LPS and LPP (samples are given at the end of this chapter). The items in the LPS came from reviewing cases and noting the presenting problems during the first few sessions. Does the LPS help you identify what areas of your life are not under control? Does the LPP help you make distinctions among the various aspects of your life?

The Life Perception Profile helps to identify the life areas which are stressful. Then I start a discussion about a stressful topic, and classify the client's statements using the basic control-theory concepts. We continue the discussion until I believe that I know about all aspects of the control system regulating the perception under discussion. The outcome of the therapy discussion is a decision about what to change. Is it the input function, which creates the perception? Is it the memory/comparator function, which defines the reference perception and calculates the error signals? Is it the output function, which produces the action?

This approach to diagnosis departs from the traditional approach, which uses the latest diagnostic and statistical manual of the American Psychiatric Association (DSM-III-R). The control-theory approach to diagnosis is based on the perceptions of the person seeking help, because they have proven to be the important ones to know, in my experience. The DSM-III-R diagnosis is based on the therapist's classification of the client in terms of the manual's diagnostic categories, which were defined in reference to similarities a panel of experts felt they saw in various groups of people. The categories in the manual reflect different kinds of mental "disorders" as seen from the point of view of experienced clinicians. The panelists believed that they had come across these disorders in their clinical practice, but you can see that they represent *combinations* of clients' problems and clinicians' *generalizations* about them. Thus, they are applicable only on the average. Much of the work of traditional clinicians involves discerning why a solution achieved by a previous "similar" client does not work for the present person, and what adjustments to make to relate to this individual.[5]

14.3.1 Reorganization

The goal of therapy is to help people learn how to regain control over the aspects of their lives in which they experience chronic error. Reorganization is the name of the change process. The reorganization system is triggered into action by error signals in the intrinsic system, the inborn control systems regulating the internal state of the body. When chronic error signals occur in the intrinsic system, reorganization initiates changes in the acquired systems (the learned hierarchy). The change begins with nonsystematic trial and error, and stops when the error signals in the intrinsic system disappear. Changes occur in the person's ability to perceive and act. A new control system forms, or an old control system modifies.

The change process is the heart of therapy. The description of reorganization just given raises the question of the therapist's role. If change is random, why go to a therapist? How can the therapist help? The main reason people seek therapy is that the reorganization process is scary. When a person is afraid, cognitive functioning and problem solving deteriorate. Therapists can be emotionally supportive. They can offer educated opinions about certain directions of change which the patient is considering. Some therapists suggest directions of change for the patient to experiment with. If the patient becomes dangerous to self or others, a therapist can intervene protectively.[6]

14.3.2 Control-Loop Aspects of the Treatment Process

Perceptions

A key concept in control theory is that of controlled perceptions. The meaning of an action is determined by the perceptions which the actions control. What are typical problems seen in clinical practice, in terms of clients' perceptions? (1) A client may be misperceiving a person or a situation. For example, a client may perceive danger in a situation where there is minimal danger. (2) A client may not be able to perceive something well enough. For example, some individuals cannot read the body language of others well enough to keep from missing important social cues. (3) A person might lack good reality contact because of distorted, disorganized, or unstable perceptions. Cases of severe psychopathology are in this class of problems.

Control theory offers two important tools for exploring perceptions. One is the description of the hierarchical order of perceptual variables. The other is the Method of Relative Levels. The 11 levels of perception are useful to keep in mind when talking to a client. People differ in the level of perception from which they typically perceive and communicate. People whose actions tend to control perceptual variables of the upper levels in the hierarchy are said to be capable of considerable abstraction, while people who are said to be more concrete are operating mainly at lower levels of perception. An obvious example of this is that one must speak to children differently from the way one speaks to adults.

The 11 levels of perception are also useful to keep in mind when one is inviting a person to self-observe. Powers' model implies that a person cannot have awareness of perceptions at the same level as, or higher levels than, the one from which he or she is functioning. For example, if a person's highest level of functioning is the category level, then the person can become aware of relationships, events, transitions, configurations, sensations, or intensities. Such a person cannot become aware of categories, sequences, programs, principles, or system concepts.[7]

The Method of Relative Levels is a valuable procedure for exploring and increasing an individual's highest level of awareness. It consists of encouraging one to "go up a level." Suppose a person uses a word or phrase which seems to be clinically significant. I would want to know what it means to the person, so, I might say, "Tell me more about it (the word or phrase) so I can experience it as you do. Describe it (the word or phrase) in the present tense, as if you were seeing it now." I look for body language signs that my client is "going up a level" —signs of surprise, puzzlement, increased excitement.

A person gains insight into a problem when seeing it from a higher perspective. Because conflicts between systems of the same level result in behavioral "hangups" or endless oscillations between opposed goals, being able to "look down on" the level where there are systems in conflict allows resetting of the opposed reference signals to values which coordinate them (performed by the level above).

As an illustration of a common type of perception problem, misunderstanding, consider a person "understanding" someone else at the wrong level of perception, too high or too low. Often, the person being misunderstood will say, "You are putting words into my mouth," or "You don't seem to have the whole picture." If it is a situation which is being misunderstood, we might notice that our actions are wrong. For example, a person who misperceives what day it is may miss an appointment. A person who misperceives how close to the curb his or her car is when parking may sense the car wheels banging into the curb. A person who misperceives a stranger for a friend might call out the friend's name, and then say, "Sorry, I thought you were someone else."

The ability of a therapist to understand client's perceptions is called "empathy." Empathizing enables one to make improved guesses about what another might be misinterpreting. I try to model the difficult process of understanding someone else's perspective, experiencing things the way he or she does, by understanding my client's perspective. I also try to involve the perspectives of other people, having different people describe the same incident. The different versions enable me to point out the importance of perspective. A perception starts from physical energy at sensory receptors, but it is a creation of the person.

One must trust one's perceptions. However, one must also realize the subjectivity of perceptions. They are not facts about the objective world, even at the lower levels of perception. At the higher levels of perception, the importance of a "trust but verify" attitude is most important. If I judge that a client is misperceiving something, I attempt to help him or her come to the same conclusion. I might point out at least one other possible meaning, or I might try to get him or her to generate possible alternatives. I could simply say something like "I think you may be misreading this." I might also challenge the patient to prove his or her case.

Extreme cases of misperception are delusions. These are very difficult to get people to modify. In one case I have known, a client believed that "Everyone hates me. They are jealous of me. They want to put me down." In keeping with this belief, he got into physical fights with others. In an outwardly different kind of case, that of anorexia, people misperceive their body size. They see themselves as fatter than they really are. As a result, they often starve themselves.

It is possible that a person might not be controlling a perception because of being unable to perceive it. For example, a child might notice that his parent becomes angry, but may not know why. The child may not see the relationship between his actions and the anger of his parent. By asking the child questions to draw awareness to the relationship, often I am able to help him or her see the relationship. He or she then can choose to alter the disturbing actions or not. A child who does not perceive the relationship cannot control it.[8] In this example, the child must learn to notice the relationship between his or her actions and the parent's anger. Then he or she can set a goal to perceive lower levels of anger in the parent, and take actions to minimize disturbing the parent. (Of course this assumes that the parent's anger is not random; if it is, the child might plunge into chronic reorganization, and finally end up with "learned helplessness," as discussed in Chapter 11 in reference to the work of Seligman.)

Cases of distorted, disorganized, or unstable perceptions are the hardest to change. The word "psychotic" applies to such cases in which the victim is said to be "out of contact with reality." Often, psychiatric drugs are used in treatment of psychotic conditions, despite the potential for bad side effects. Control theory offers some interesting ideas for understanding and possibly treating psychoses. I have worked with a young woman who experienced hearing voices. The voices said mean, nasty things to her, relating to the issue of her mixed racial identity. She experienced these voices as coming from outside of her. She would become angry at the voices for bothering her. She would state that she was looking for the person who was talking, and would slit his or her throat if she found him or her. I use the following analogy to explain ideas such as these. Most people have watched movies on television. Sometimes the movie is being broadcast at the same time as we view it on television; this is like perceiving something in the environment. Sometimes the movie comes from a videotape in a recorder/playback unit; this is like imagining and remembering it, based on memory. Normally, a person knows whether his or her perceptions are based on physical energy in the environment (like a television broadcast) or memory recordings (like a video tape). When one is hallucinating, one is perceiving based on memory recordings. However, one misperceives the hallucinations as based on current perceptions of the environment.

Why does this kind of misperception take place? The person's self-control system does not include it in the self-image. Therefore, it seems as if one's brain did not create this perception. Thence, it might seem most plausible to the person that the voices must have come from someone else. It is a logical deduction. In cases of multiple personality disorder, in contrast, a person experiences the voices as coming from within, because he or she can link each voice to one of several self systems.

Control theory contains some treatment suggestions for people who are hallucinating. In the case of the woman hearing the voices, one approach I used was that of trying to get her to believe that the voices were created in her brain. When she rejected this idea, I suggested (from an implication of control theory) that she should try to influence her experience of the voice in some way when she heard it. If she could will the voice to change (sex of speaker or language of speaker, for example), then it would support the idea that she controlled the voice. The strength of her rejection gradually grew weaker. She explained that she feared losing confidence in all her perceptions if she accepted my idea.

Control theory suggests that psychotic symptoms can eventuate from endless brain reorganization due to chronic error signals. Thus, psychosis can be a solution (though not a very desirable one) for chronic reorganization. A person who has become psychotic has found a solution to life's problems. The woman with episodic auditory hallucinations admitted to me that, if the voices stopped, then she would have no excuses for not socializing. She also reported that the voices became more frequent and stronger when she was experiencing stress in her life. In extreme psychotic conditions, the individual who lacks both socializing and work skills, thus keeping him or her from supporting himself or herself through working, has solved those problems—from an environment-control point of view—by having made himself or herself "eligible" for support from others in an institution. Therefore, before a person becomes psychotic, efforts should be made to recognize and manage the stress which is present. Parents, schools, and employers need to be better educated on the topic of stress and the signs that a person is moving in the direction of a psychotic solution to life's problems. After people have developed psychotic symptoms, it is very hard to reach them with psychotherapy. The psychotic symptoms serve to protect them from further error signals. Metaphorically speaking, they are watching video tapes instead of receiving live broadcasts. The accepted treatment approach consists of putting psychotics in disturbance-reduced environments (hospitals), giving them anti-psychotic agents which reduce some of the psychotic symptoms, and providing nice people to take care of and talk to them. Unfortunately, there are negative effects of being hospitalized, and undesirable side effects from the anti-psychotic agents.

The use of anti-psychotic agents stops some of the psychotic symptoms. The approach of biological psychiatry is that the psychotic symptoms are the results of a biological disorder in the brain. For example, some important chemicals in the brain may not be at the right concentrations. Some brain cells may be undergoing seizure activity. In short, psychotics have brains which are "broken" in some way. A stimulating treatment of the topic of psychotic conditions is a book by North (1988), who gives a first-hand account of what is it like to be "schizophrenic." North went on to complete medical training and become a psychiatrist.

Does control theory offer any novel suggestions for the treatment of psychotics? I believe we have to get the psychotic person to start reorganizing again. Psychotics have simply come up with an incorrect solution to life's problems, and have then cut themselves off from environmental feedback effects. As humanely as possible, I believe, we should try to induce error signals. This might mean placing the psychotic person in a strange enviroment. Examples which come to mind are the kinds of special effects being created by movie studios. The use of electric shock (by means of a cattle prod) sometimes has been found to be effective in stopping life-threatening, self-injurious behavior of autistic people. Perhaps the effective component of this apparently cruel treatment is novelty (unexpectedness), which starts the reorganization process. If novelty is the effective treatment component, then the use of painful stimulation can be eliminated, while other novelty-inducing approaches are developed.

Reference Values

Most perceptions have a preferred state. In controlling a perception, one acts to achieve and maintain it at the preferred state. The preferred state is called the reference perception. Some of the psychological problems of people seem to involve problems of reference values or levels. Here is an example. A preschool child saw his ball roll into the street. He wanted to get the ball, and he wanted to obey his mother, who must have told him not to go into the street. (At that moment, he was paralyzed by a conflict between two opposing reference states of equal strength.) His solution was to ask me to retrieve the ball for him as I walked by.

Some people have goals (reference states) which are very difficult or impossible to reach or maintain. For example, some people are perfectionistic and not very flexible about their goals. One case I had of this nature involved a man who experienced considerable stress at work. The work load increased to the degree that he could not do the quality work he demanded of himself. A related problem which I encounter in some young people is that they do not know what to want. I have had many cases of younger people who did not know what they wanted to do with their lives. They incur stress from frantically trying everything in sight. Others want too many things and try to accomplish their goals in too short a time. These people run out of time or energy to do all of the things they want. They wear themselves out.

People who do not know what to want lack experience in deciding. They lack confidence, are passive, and have a poor sense of self. During therapy, they must practice deciding, to gain awareness of the importance of their opinions, likes, and dislikes. They are important, and they matter. I spend a lot of time listening to them and getting them to talk. Time is spent discovering and describing their preferences. In cases of people who have a history of being submissive to others, I try not to use a directive style.

People with too many goals experience stress from the inevitable time conflicts which occur. These often are very competent people. The goal of pleasing people is often a higher-order goal behind their high level of activity. However, they often stress other people around them with the high level of activity. Another common higher-order goal is to avoid being bored. They have to learn to monitor the number of active goals, and to keep the number within manageable levels by saying no to new goals. I have found that going over time-management skills is helpful in these cases. It is also helpful to coach these people in relaxation skills. People with too many goals have to learn that they have limits, and that their bodies require some relaxation time.

In all of these procedures, the test for the controlled variable can be extremely useful. It is the control-theory tool to discover or confirm reference levels. The reference perception is the value of the perception which results in no further action taken to obtain the goal. As I indicated above, I often make an educated guess about what my client wants, then disturb this perception by an action or statement. If he or she is controlling the perceptual variable, I expect to see it restored to its original value. We can explore how suitable it is in relation to his or her other goals. We might then discover internal conflicts between equally strong but inconsistent reference states.

The approach to resolving a conflict involves guiding a patient's awareness. Once a therapist notes conflict, the task is to direct the patient's awareness to the two goals in conflict. This may also require use of the Method of Relative Levels. In order for the patient to perceive the conflict, he or she must be viewing it from a higher level. The therapist helps the patient "go up a level," until a level is reached where the conflict does not exist. It is to this level which the patient's awareness must be directed. Changes in awareness can start the reorganization process. The reorganization will eliminate the conflict at the lower level.

Therapists do not have to be right on the first guess. The guess can be revised and tested again repeatedly until the best possible description is obtained. From the point of view of the patient, the therapist may seem to be clarifying, paraphrasing, asking for more information, or offering interpretations. Testing for controlled variables in conflict is a trial and error process, similar to that facing parents of a baby who is crying. The parents make guesses about what the baby wants and then they test each guess. Is the baby hungry? Is the baby wet? Does the baby want to play? When the parents hit upon the correct reason, the baby stops crying and calms down.

Gossen and Good (1988) have suggested the "and" technique to resolve conflicts. A person combines the two conflicting perceptions with the word "and." Then the person tries to figure out a perception which will make the compound statement true. This technique encourages a person to change levels in order to make the new statement true.

An especially difficult type of conflict is seen in the case of perfectionistic people. They can be viewed as people who have very high sensitivity for error signals. They are afraid to be wrong, and often come to therapy with complaints of anxiety. They do not like change. They like to keep their lives the same as much as possible. At the same time, many perfectionistic persons have reference values to please other people. Their obsessions and compulsions function to avoid rejection from significant others. Their conflicts are between the tendencies to resist a therapist's suggestions and the desire to please. They often come across as rigid and difficult patients. Of all of the techniques for resolving conflict, Powers' Method of Relative Levels often proves most useful with perfectionistic people. When a person is taken to a level of perception at which he or she stops resisting the therapist's suggestions, he or she is free to change. This approach takes time. The person has to be willing to stay in therapy long enough to discover the conflicts and work through them. In working with perfectionistic people, I have used the following techniques as supplementary to the main focus of resolving conflicts. I try to get the person to broaden what he or she wants and how he or she will get it. This increases the chance of success and reduces frustration. It helps the person to think in terms of alternative goals and means to achieve the goals. I try to get the person to deliberately introduce changes into his or her life. If he or she accepts the suggestion, he or she will see that nothing terrible happens. I try to get him or her to be "selfish" and to be a "bad" boy or girl for a change. Perfectionistic people have very strong moral and ethical codes. They may not be interested in or skillful at having fun. I teach them some relaxation skills to get them used to the idea of letting go of themselves. They may learn that they don't have to control themselves so tightly all of the time.

The extreme version of the perfectionist person is the one diagnosed as having an obsessive-compulsive disorder. In these cases, anti-depressant or anti-psychotic agents may be helpful.

Consider the case of people who frustrate themselves because they choose goals which are uncontrollable. One common example is the case of person A, who wants person B to be a certain way. This works out fine as long as person B happens to have the same goals, but when this is not the case, person A will be frustrated and disappointed, or persons A and B will be in conflict with each other. As Ford (1989) explains, the solution to this sort of problem is to recognize that a goal is uncontrollable and then give up that goal. From an analysis of why the goal was important, a substitute goal can be chosen which comes as close as possible to meaning the same thing as the original goal. The substitute goal, however, is reachable and maintainable for the person.

Error Conditions

There is a class of psychological problems which is most closely linked to the control-theory concept of error conditions, rather than to perceptions or reference perceptions. Recall that an error condition starts, stops, and guides skeletal muscle activity, resulting in actions in the environment. The same error signal also increases, decreases, and guides the body's arousal. The degree of arousal must be appropriate to the energy requirements of the action. Emotion (feeling) in control theory is a perception of a body state which starts from an error signal. Some recent references on the topic of emotions are Frijda (1988), Greenberg (1989), Plutchik (1988), and Strupp (1989).

What are the typical error-condition problems seen in clinical practice? Some people do not verbally or gesturally express feelings, and this creates problems for them. They are very private, quiet, inhibited people, whom other people find hard to read because of their emotional nonexpressiveness. Thus, social relationship difficulties result.

Some people do not have higher-order representations which they can use to understand what they are feeling in the body; this creates problems for them. People with this sort of emotional problem seem cut off from their own body experiences. When they decide, feelings do not receive much weight. This results in logical decisions which ignore the information contained in feeling reactions. As a result, the decisions may disturb other people, sometimes resulting in rejection or noncompliance. People who find it hard to know their own feelings often develop psychosomatic diseases in which they experience pain or bodily dysfunction.

Some people experience bad feelings which are strong, frequent, or changeable. These emotions result in concentration/attention, memory, or decision-making problems. It is hard to function well cognitively when emotions are too strong. This makes it hard to work at solving a problem. If emotions are strong, frequent, or changeable, then a person is having strong, frequent, or changeable error signals. This triggers the reorganization process, which directs awareness to the control systems having error signals. Thus, awareness is directed away from the task at hand to the problem areas; the cognitive dysfunction follows.

I have found that it is helpful to keep the levels in mind when talking about feelings with people. Even people who have a hard time talking about their feelings can tell you something about the feeling at one of the levels. It is not necessary to have a client verbally categorize the feeling. The minimum requirement is that a person can recognize that he or she is feeling something when it is obvious from the body language that he or she is having a strong emotion. Then a therapist can follow up with some additional questions. What was the person wanting to happen when he or she had the feeling? What was he or she perceiving as happening when he or she had the feeling?

I call this approach to working with a patient's feelings the "feeling-wanting-perceiving" method. If successful, the method will clarify the nature of the error signal behind the feeling. This may suggest the kind of action which would reduce the error signal. For people who experience but do not adequately express feelings, writing in a journal is sometimes a successful technique. It allows communication without confrontation. The more introverted person in a couple can express thoughts and feelings in a way which gives the desired privacy. In a hospital setting, one finds other kinds of therapies designed for the nonexpressive person. Some of these alternative therapies include art, music, drama, and movement mediums. The purpose of encouraging emotional expressiveness is to help a person achieve an integration of thought, goal, feeling, and action.

People who do not experience feelings such as joy, sadness, etc., are hard to help. Biofeedback therapy can help them become more sensitive to body experiences. Biofeedback therapy is the use of electronic machines to check body states and feed the information back to the person. This helps the person become more aware of his or her body states. In that feelings are perceptions of body states, biofeedback therapy can help a person become more aware of feelings. It can also help a person learn to relax the body voluntarily. This reduces the perception of stress.

People with very strong or highly variable feelings often demand the help of psychiatric drugs to reduce or stabilize their feelings. They find it hard to engage in psychotherapy until they have some relief from symptoms. Thus, the use of psychiatric drugs on a temporary basis may be a necessary supplement to psychotherapy for these kinds of cases.

Not all perceptions of the states of the body start from error signals. Some may result from diet, physical disease, seasons of the year, etc. Moods are definable as perceptions of body states which are not a function of any specific error signals. It is possible that some cases of mood (affective) disorders may be the result of causes other than error signals. The applied control theorist has to be open to these possibilities. Referral to the appropriate health care professional will be necessary in these instances.

Actions

Some people arrive with difficulties at executing the actions which would help to alleviate the error conditions. What are the kinds of action problems which one sees in clinical practice? Some people lack the actions which would reduce the error signals. These cases are common among children and developmentally disabled persons. Some people have the skills, but never apply them for some reason. An example of this kind of case is a business executive who functions effectively in groups at work but who does not apply the interpersonal skills to his marriage.

Disturbances

The environment does not stay the same. Even if a person can perform actions which reduce error signals to zero, changes in the environment can induce new error conditions. Some psychological problems seem most strongly linked to the concept of disturbances. What are the kinds of disturbance problems which present themselves in clinical practice?

Anything and everything bothers and upsets some people. This is usually a sign that they are experiencing chronic error signals, and are beginning to reorganize. Other people show that nothing bothers or upsets them. These people are defending against chronic error conditions. Control theory helps us to understand that a stimulus is a disturbance only when the person can perceive it and has a goal with respect to the perception being changed. A parent may be upset by the condition of a child's room. The child may perceive that it is messy, but not have a reference value for neatness. Or the child may have a goal for neatness, but doesn't perceive the room as being messy. In either case, the same room causes an error in the parent, but not in the child. Some kind of action is taken by the parent, but the child does not have an urge to act. The objective condition of the room cannot be the cause of action in the parent and the lack of action in the child. Control theory assigns responsibility to the person, not to the environment, for error signals.

Error signals may continue even after a person tries to change the environment or himself/herself. Under these circumstances, a person can separate from the environment. This is when a therapist may advise a person to consider the option of leaving a marriage, neighborhood, or job. This solution may be better than suicide, homicide, becoming physically or mentally sick, criminal actions, etc. This is sometimes a judgment call for therapist and client.

14.3.3 Other Approaches to Clinical Psychology

Many clinicians are becoming more eclectic in treatment approaches. This means that they are willing to use any treatment method which works for a person's problem. Some authors also claim that treatment approaches are becoming more similar to each other. Beitman (1987) outlines what is common to all individual therapies. (See also Messer, 1986; Lazarus, 1981; Rotter, 1964.)

14.4 A Control-Theory View of Healthy Personality

Most theories of personality, therapy, and psychopathology provide pictures of the way people would be if they were free of psychological problems and functioned in a way consistent with their human nature. What is a control-theory vision of healthy personality? It is generally synonymous with a conception of "natural" human nature. It is the condition toward which we hope people move in therapy, or the condition of people who never needed therapy.[9] For instance, many of my clients ask, at some point, how long therapy will last. One answer I like to give is "When all of the different LPS areas which matter to you are in the 'OK zone'." Another answer (which I believe means essentially the same thing) is "When your self description approaches that which would be given by a psychologically healthy person."

Imagine that we obtained the self-image description from a person who functioned according to the control-theory vision of human nature. Suppose that we used the strategy described in this chapter for obtaining self-image. Imagine that the person gave us the following answer when asked to instruct an actor who was going to play him or her in a movie about his or her life:

> You are a person in whom error signals are kept close to zero. This means that you are successful in achieving and maintaining goals regardless of environmental obstacles. You are a person who selects your own goals and the ways to reach them. You do not let circumstances or other people do this. This includes the goal of the kind of person you are. Goal selection is done in a way which avoids internal conflicts. You are a person who is internally consistent. Internal conflicts, which are a major source of error signals, are addressed and resolved.
>
> You are a person who can become aware of your own experiences. This means that you can become aware of any level of perception within you from the systems level to the intensity level. This ability to shift awareness is important for monitoring error signals and for learning.
>
> When minor enviromental changes occur, you are a person who adjusts actions automatically. You are flexible when it comes to the means to your goals. When major environmental change makes old ways of controlling ineffective, you are a person who can learn new ways.
>
> You are a person who prefers reducing error signals by realistic means (actions in the environment) rather than by psychological defenses. This is because only actions in the environment can lead to long-term reduction of error signals.
>
> As a result of successfully controlling your life, you mostly experience positive emotions, not negative emotions. You often feel calm and relaxed, not stressed. You are a person who lives in harmony with others. In this way you avoid the error signals which can result from interpersonal conflict and disturbing others. Good communication and social skills are important to allow you to live in harmony with others. You are a person who addresses and resolves conflicts with others in a democratic way. You understand that other ways of dealing with interpersonal conflict lead to chronic error signals in the the long run. You will treat each person in a unique way. You will not treat them in a standard way.

The Golden Rule in control theory might read: Treat others the way they want to be treated. One cannot assume that everyone has uniform goals.

Andrews (1989) discusses the views of human nature in several theories of personality, therapy, and psychopathology. At the end of his discussion, he comes out in favor of the what he calls the existential view. The control-theory and the existential views seem similar. Students might pursue the study of other views of human nature by referring to Andrews' article.

14.5 Clinical Research

The foregoing discussion has pointed out the possibility of developing some new cognitive-ability tests based on the control-theory levels of perception. I am working in a developmental center for adults with mental retardation and psychological problems. The standard methods for evaluating cognitive abilities in this population have limited usefulness. If we could assess which levels of perception a person could control as he or she goes about his everyday activities, then this would be potentially very useful. For example, suppose that we learned that a person could control sequence perceptions (and lower-level perceptions), but not any perceptions at a higher level. In devising ways to teach activities of daily living (for example, washing and drying hands) to such persons, we would be careful to avoid the use of levels of perception higher than the sequence level (for example, by avoiding program level rules which would alter the sequence of steps, depending on circumstances).

Some control-theory clinicians are in the process of developing new personality tests. Control theory may lead to new ways of scoring standard personality tests, such as the TAT[10] and the Rorschach. When scoring the TAT, I have used the concepts of perception, reference perception, error condition, action, and disturbance to summarize the story a person tells for a picture. I have used the levels of perception to code each statement in a TAT story. When scoring the Rorschach, I have used the levels of perception to code a person's response to an inkblot stimulus. The advantages of using the control-theory concepts to score these tests could be investigated in future research.[11]

New clinical research methods will doubtless follow the lines of Maher's (1988) discovery-oriented suggestions. Maher advises that we take a much closer, detailed look at what happens in psychotherapy. One approach consists of choosing some psychotherapy event or phenomenon which is of interest. For example, one topic which is of interest to me is what impact therapy has upon the development of morals and personal standards for judgments. Examples of this phenomenon could be obtained for a given case over several sessions. The levels of perceptions could be used to classify the levels on which a person's morals resided. We could examine the data for what they suggest about the effect of therapy upon the process of forming moral judgments and drawing inferences.

A second discovery-oriented approach consists of studying sequences of interaction between the therapist and client. For example, if the therapist uses the Method of Relative Levels to explore topics, what changes take place within the client? If the client is in conflict, what are the best ways the therapist can help him resolve the conflict? Given that the client has reorganized, what role has the therapist played in achieving this? Data specific to each of these questions could be obtained by examining therapy audio or video tapes.

Control theory provides a unified approach to psychological evaluation and treatment. Much research needs to be done to evaluate the utility of control theory in clinical practice. Students are invited to join this exciting adventure.

Notes

1. Performance on the pursuit tracking task has not been applied to any further practical matters to date. It will require additional research to learn what else of interest it might tell about a person.

2. An alternative approach is to use the idea of error sensitivity. Rather than trying to change the degree of self-awareness, a clinician might target the error sensitivity of the person for deviations from the self-image. Error sensitivity is the amount of corrective action produced for a given amount of error signal. A person with a high self-consciousness score might have a higher error sensitivity score for deviations from the self-image. Powers is working on modelling different approaches to how error sensitivity might be changed.

3. The statistical analysis done on the data (correlations; factor analysis) is not completely mechanical; some room is left for the judgment of the person doing the analysis. Norms are not necessary to interpret the results. Individual case studies (that is, n = 1) are possible.

4. It is beyond the scope of this introductory chapter to describe each of the individual tests in detail, and the kinds of contributions they will make to the psychological evaluation.

5. Interested students can learn more about the DSM-II-R in abnormal psychology courses.

6. The specific course followed by therapy is often unpredictable, because of the nature of reorganization. Powers (1973) has compared the reorganizational changes during psychotherapy to the task of two people unraveling a ball of yarn together.

7. See Robertson (1985) for a case report on an individual with almost no self system, and whose values therefore were controlled by other people, with minimal influence from her judgment as to what would be beneficial for herself.

8. Powers (1979) has described the sequential development of a new control system as a sequence as first perceiving a new variable of stimulation, then settling on a value of this variable as the reference level (probably the perceptual value most frequently recorded in memory), then learning how to use the existing control systems to achieve and maintain that perception at the reference value. The first phase of control system acquisition is the coming into existence of a new sensitivity or ability to perceive. This step sometimes is called perceptual learning. For further views on this topic, see a book on perceptual learning and development, such as that by Gibson (1969).

9. Whether there can be perfectly "natural" people in complex modern civilizations is controversial.

10. The Thematic Apperception Test, in which the client tells stories about pictures, and the clinician then interprets the projected self-image of the storyteller.

11. I have started to research the LPS and LPP tests. Some of the questions of interest to me include these: Are the 38 topics comprehensive enough? Can the LPS and LPP be used to track progress in therapy as intended? Is the number of life areas indicated as problematic related to the overall stress level of a person? What is the best way to follow up on the problem areas identified, in order to "zoom in" on the controlled perceptions?

Also, I have completed a pilot study on the use of control-theory concepts in psychotherapy. I have found that it is possible to code live sessions using control-theory concepts. However, this is a difficult task which places an additional burden on the therapist. The preferred methodology would be based on coding videotapes of the therapy sessions, rather than live sessions. The research would be aimed at improving the way a therapist identifies problem control systems, and improving the way a therapist guides a person through reorganization.

Record Form Used by David M. Goldstein

PSYCHOLOGICAL EVALUATION

Name:

Address:

Identifying Information:

Reason for Referral:

Tests Given:

Observations During Testing:

Description of Person Based on Test Results:

- PERCEPTIONS:
- REFERENCE PERCEPTIONS:
- ERROR CONDITIONS
- ACTIONS:
- DISTURBANCES:

Treatment Recommendations Based on Test Results:

Life Perception Survey (LPS) Developed by David M. Goldstein

LIFE PERCEPTION SURVEY

Which areas of your life are NOT going OK? Circle the associated number of each of the following areas of your life which should be changed, improved, or made better in some way.

1. marriage
2. money
3. child(ren)
4. work/job/career
5. physical health/condition
6. psychol. health/condition
7. school
8. brother(s)
9. sister(s)
10. friend(s)
11. body appearance/condition
12. parent(s)
13. relatives (aunts, uncles, etc.)
14. physical environment conditions
15. family life
16. social life
17. strangers
18. material stuff/posssessions
19. day-to-day time schedule
20. the way free time is spent
21. the use of substances
22. house, neighborhood
23. concentration/paying attention
24. memory
25. decision making
26. feelings/moods
27. thoughts/images/sensations
28. sleeping
29. religious/spiritual life
30. sex life
31. eating/food
32. status with police/courts
33. self-image
34. life goals chosen
35. success in reaching life goals
36. conflicts
37. talking/understanding people
38. movements/motor coordination

Instructions: Consider only the life areas circled. The three most important ones are (write in the associated numbers):

___ ___ ___

Life Areas　　　Describe the Change Wanted

Life Perception Profile Developed by David M. Goldstein

LIFE PERCEPTION PROFILE

Instructions: Refer to the Life Perception Survey.

Step 1: The three MOST OK areas of my life are: ___ ___ ___

The three MOST NOT OK areas of my life are: ___ ___ ___

Cross out the six life area numbers which you used above:

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38

Step 2: Among the remaining life areas,

The four MOST OK areas of my life are: ___ ___ ___ ___

The four MOST NOT OK life areas are: ___ ___ ___ ___

Go back to the life area numbers of step 1 and
Cross out the eight life area numbers which you used in step 2.

Step 3: Among the remaining life areas,

The six MOST OK areas of my life are: ___ ___ ___ ___ ___ ___

The six MOST NOT OK life areas are: ___ ___ ___ ___ ___ ___

Chapter 15

New Psychological Research and Applications

15.1 Introduction

When scientists introduce a new theory—a new way of understanding reality—they typically devote considerable energy initially to offering evidence that it "works." If it is a theory about how to do something, the attempt is to prove that it has the looked-for results. If it is a theory for explaining something, the attempt is to demonstrate that it explains things which its predecessor (and rival) cannot explain, or explains inconsistently.

I (RJR) have observed both of these processes in the course of my career in psychology. First was the then-new "Client-Centered Therapy" of Carl Rogers (1951). He pioneered in applying psychological research to evaluate his new method of doing psychotherapy. The initial studies on this approach were devoted to determining whether his method worked—that is, whether individuals treated with the client-centered approach gained improved mental health as compared with similar people who remained untreated. Later on, after establishing that client-centered procedures did work in many cases, further studies went into the more specific questions of how well it worked, with whom, under what conditions, what the effective ingredients were, and many other questions concerning details. Eventually, these early studies grew into the major specialty of psychotherapy research, involving many of the different therapeutic schools, and still continuing to develop at present (see Garfield and Bergin, 1978/1986; Howard, Kopta, Kraus, and Orlinsky, 1986; Kiesler, 1973; Parloff, London, and Wolf, 1986; Rice and Greenberg, 1984).

The other process of developing and evaluating a new approach which I have had the pleasure of observing has been that of the Control Systems Group, with initial research studies aimed at testing Powers' hypothesis that behavior is the control of perceptions, rather than actions. Group members pioneered new research methods in the course of promoting the paradigm revolution in basic psychological theory represented by Powers' postulate, as shown in this volume. The fundamental nature of the new direction perhaps has been expressed best by Marken (1988) in a paper distinguishing the fact that humans control their perceptions from the research methods needed to analyze how this is done, and by Runkel (in press), who discriminated two fundamentally different methods of behavioral research: the method of relative frequencies and the method of specimens.

Runkel describes the method of relative frequencies as a method useful for counting occurrences and events, tabulating their relative frequencies, cross-tabulating the extent to which sets of events occur mutually, and computing the probabilities that particular observations could occur by chance. He argues that this method (originally developed for the improvement of agriculture) has been misapplied in much psychological research, probably because there were few alternatives when psychological research began. It was misapplied in the sense that, while most psychological research ostensibly has been directed at determining the *nature* of human nature, the method of relative frequencies is a method for measuring proportions of occurrences of specified kinds in masses of observations. The people or animals upon whom the observations are made must be regarded as *identical* to each other with regard to the phenomena of interest —they are viewed simply as its "carriers." When used to investigate the nature of behavior, this method often resulted in ignoring many salient facts about what people and animals are really like, as Liddell pointed out in his work on experimental neurosis, cited above (Chapter 1).

The method of relative frequencies is effective when one is interested in phenomena appearing only in the aggregate. No one cares, for example, what any individual molecule in a gas is going to do next, or how one kernel of corn differs from another. That is why statistical assessments of the effects of different forces acting upon them (temperature and pressure in the former instance, moisture and fertilizer, for example, in the latter) can result in useful information.

However, to the extent that the aim of psychology is to understand the nature of human beings, it calls for the method of specimens. Runkel explains how this method is aimed at determining the essential qualities which are invariably found in all members of the species, and thus serve to characterize it. Early psychological research, such as psychophysics, the studies on rote memorization of Ebbinghaus (1885), and much of the work of the Gestaltists (cf. Kohler, 1947) did report findings which are charactistic of human beings in general, but their methods had limited applications and eventually declined in importance in the field as a whole.

What is needed is a shift in emphasis from descriptive approaches to model building. The building and testing of models of invariant features of human functioning by members of the Control Systems Group represents a new approach in psychological theorizing and research, as shown in the following brief review.

15.2 Tracking Targets

Tracking of various kinds of targets is one of the most universal human activities. In following the play of two hockey (or any other sport) teams, hitting a tennis ball, swatting a fly, keeping one's car in the lane on a road, moving the eyes over lines of written words, avoiding the splash of fast-moving cars on rainy streets, or watching children run about at play, we are performing some variation of tracking targets. How do we do it?

Traditional explanations in psychology derive from the assumption that the target must function as a stimulus, to which the actions of tracking are a response. This simple formulation sounds all right, at first glance, in words. But it doesn't really explain anything. You can't build a robot to duplicate any tracking actions with this explanation. Several members of the Group investigating control theory are following Powers' lead in studying tracking tasks on computers, allowing analysis of what is happening (Marken, 1980; McCord, 1982; Goldstein and Sabatina-Middleman, 1984; Goldstein, Powers, and Saunders, 1987). Tracking tasks consist generally of a computer target which is being moved up and down or side to side in a regular pattern or a pattern disturbed by random variations. The subject must match the movements of the target by using a game paddle or steering arm. The object is to maintain a match between target position and the cursor controlled by the subject. (Recall Goldstein's description in Chapter 14.) The task may be made more difficult by random disturbances added to the target's and/or the subject's movements.

It was no particular surprise to anyone that people can learn to track targets with reasonable accuracy in relatively short periods of time, despite the added difficulties from interposed disturbances. Then Powers showed that the simultaneous equations for a control system (as presented in Chapter 4 above) permit a computer simulation of the data created by the subject. This suggests that the actions a person performs in tracking a target might, in fact, be controlling the subject's perceptions in the manner modelled by the control-theory equations.

15.3 Extensions of Control-System Research

Following the initial measurement and simulation of tracking behavior, there have been many further developments. Marken (1985) developed a computer demonstration showing that a person could keep a cursor near a target on a computer even though the cursor moved in a random direction whenever it began to move, and the person could only stop its movement. This demonstration was inspired by Koshland's (1980) study of the feeding behavior of *E. coli*, which was mentioned in Chapter 6; there, it was noted that this bacterium cannot steer, yet it gets where it is going by its ability to stop moving and then start again in a new, random, direction, whenever its current direction is not optimal (that is, not moving toward food). It usually surprises students to discover that one can "get somewhere" via random movements, simply by stopping them whenever they are not in the right direction.

Marken (1989b) sees his study as showing the following: (1) a control system can operate by selecting from random results those which approximate a "goal" or "reference" result; (2) such intelligent action is a good model for human learning (when you know what you want, but not how to get it); (3) the behavior of *E. coli* implies control-system organization, because there must be a component of the system to select the results to be pursued (defined in control theory as the reference signal).

Another contribution of Marken (1986) demonstrates a model of hierarchical coordination of control behavior. See also Marken, 1989a.

Bourbon (1988, 1989) showed that social interaction can be modelled in a tracking experiment in which the subjects' independent efforts to match a target are made to interefere with each other by the computer program through which their efforts affect the screen. Each subject is tracking a different target. The actions of one of them unintentionally and unavoidably disturb the cursor of the other, whose actions do not disturb those of the first. Thus, one tracks with no disturbance, while the other must compensate for disturbance. Humans can do this successfully, and Bourbon's computer program model of each, acting as an independent control system with individual reference signals and perceptions, shows correlations between handle positions for models and people of 0.995 or higher. In a variation of this experiment, one person runs against a computer model, which plays the part of another person in real time. The events on the screen and the resulting data look like those for two people performing.

Another of Bourbon's experiments involved cooperation in tracking, in which two people produce a result which neither can accomplish alone. Again, the model predicts their behavior with correlations of 0.995 or higher. Bourbon surmised that these experiments, taken together, offer strong support for the control-theory speculations about human interaction of sociologists Tucker and McPhail (1988). This research may be the first true model-based investigation in the area of social psychology (see also Chong, 1988; Murphy, 1982).

Other control-theory investigations have examined control systems in bodily functioning. Bourbon, Johns, and Nussbaum (1982) offered control-theory analyses of physiological correlates of behavior, Hendrickson (1984) analyzed control of saccadic eye-movements, and Pavloski (1989) provided an objective definition of "stress" in showing cardiovascular reactivity to difficult tracking tasks.

Hershberger (1986), in an ingenious experiment, demonstrated that the so-called "approach response" commonly used in animal research (for example, the act of running to a visible foodcup) is a controlled perceptual input mediated by negative feedback. This was evidenced by the debilitating effects of positive feedback. Specifically, Hershberger tested hungry four-day-old chicks for their ability to approach a foodcup mounted on the wall of a long, narrow alley, with the alley providing positive feedback—as a chick moved along the alleyway, the walls of the alley were made to move in the same direction as the chick, and twice as far. So, to approach the foodcup, a chick had to "walk away" from the food cup, which would automatically overtake the chick. This they failed to do. In general, the chicks futilely chased after the foodcup, thereby evincing the runaway behavior charateristic of a closed-loop system subject to *positive* feedback. One chick learned to get to the foodcup by sidestepping, while stretching his neck upright, and pointing his beak at the ceiling. However, as soon as this chick lowered his head, he behaved as the others: if the foodcup was not immediately within reach, he chased after it briefly before abandoning the visual approach and resuming his stereotyped posture of sidestepping. This supports the hypothesis that the chicks control their perceptions, as proposed by Powers' theory. Interestingly, the "brilliant" chick, which learned to get the food by ignoring what he "saw" and sidestepping until the food cup was in reach, might have reorganized control of his feeding behavior at a higher (more abstract) level.

Other social scientists working with Powers' model, including Tucker and McPhail (1988), Delprato and Wise (1988), and Williams (1988), have demonstrated the use of control theory in analyzing and proposing new explanations for a variety of social and economic situations. Smith and Kao (1971), using K. U. Smith's feedback-theory conception, also found feedback effects in social interaction.

Applications of the control-systems paradigm are also developing in new theory and applied directions: theoretically, as with Dennis' (1988) proposal about brain functioning in the process of reorganization, Hershberger's (1989) volume on volition, Jordan's work (1986) on the illusion that people control their behavior, Powers (1980) on consciousness and (1989) on volition, and Robertson's (1983, 1984) speculations on the subjective experience of reorganization as anxiety; practically, in the clinical work of Ford (1987, 1989), Goldstein (1988 and Chapter 14 above), Gossen and Good (1988), and Robertson (1985, 1987); and in education and training, by Randlett (1988), Soldani and Ford (1983), and Tucker (1988). Presumably, this flowering of control-theory research will continue to expand upon the beginnings reported here.

Chapter 16

New Views of Some Perennial Problems

16.1 Introduction

A paradigm shift in science, Thomas Kuhn (1962/1970) maintained, does not result simply in new facts coming to light, but in new kinds of facts becoming of interest, and in new explanations for many old issues. The control-theory paradigm in psychology inspires just such reexaminations, as shown in Part 4 of this volume, and in Hershberger's (1989) volume on the problem of volition.

Several other issues of perennial interest in psychology take on a new look from the standpoint of control theory. They invite theoretical speculations, even though critical tests of such speculations may lie uncertainly in the future. These are such issues as the nature of *consciousness, determinism versus free will, attention and control, the nature of projection and prejudice,* and the role that randomness in reorganization plays in *the development of individual differences.*

16.2 Speculations on the Nature of Consciousness and Will

When the foundations of psychology as a separate discipline were being laid down in the mid-19th century, the first two schools, the Structuralists and the Functionalists, tended to equate mind with consciousness, without really offering any hypothesis as to how consciousness is produced. This problem was left unresolved as Behaviorism simply steered around it, instead of confronting it.

In fact, as recently as 1977, we find the neurophysiologist Sir John Eccles saying, "I have the indubitable experience that by thinking and willing I can control my actions.... I am not able to give a scientific explanation of how *thought can lead to action*.... When thought leads to action, I am constrained, as a neuroscientist, to conjecture that in some way my thinking changes [my] neuronal activities.... *Thinking thus eventually comes to control the discharges of impulses*... [to] my muscles." (Popper and Eccles, 1977, pp. 282-283; italics mine, RJR)

If we understand Eccles correctly in the above quote, then he is saying that a conscious thought leads to an action in the sense of *producing* it. But looking at the problem in terms of Powers's conception of how the the control hierarchy functions, we could restate the description to say that the thought *is* the perception—in the higher-order control system—of the goal which that level issues (as a reference signal) to the order below. The perception of the body's movement in the environment is being brought to match the thought of it, perceived a moment before. In other words, the conscious thought does not *lead* to the action, unless we are speaking figuratively. What actually leads to the action is a new reference signal arriving at a lower order, while what led to the thought was also a reference signal, from a still higher order. That the thought *seemed* to lead to the action is not surprising, since the perception called the "thought" preceded the perception called the "action."

In this view, "intention," "will," and "consciousness" can be seen as words reflecting different aspects of control, rather than as neural or mental functions. Intention, when it is conscious, is synonymous with will. We have already covered, in earlier chapters, the broadening of the term "intention" to equate it with "reference signal," independent of whether or not it is monitored consciously. I believe we can be aware of a current intention to the extent which it coincides with the highest order at which one is adjusting a controlled perception, as illustrated in the example of the different orders of perception to which one can attend while typing.

Recall that in the example of a program of typing something, attention was postulated to focus on what currently needs adjusting, while what is working automatically was postulated to remain unconscious *because* attention is focused elsewhere. If I perceive what I want to communicate occurring in my visual field, I keep attending to that, because the very fact that it is flowing requires continual reference adjustments to the program level, where the sentences which implement the intended communication are being composed. Should that level incur a disturbance, say from seeing typographical errors, the program interrupts, as my attention (awareness) "downshifts" to the position of my hands over the keyboard.

A conception of the underlying "mechanics" of consciousness also can be inferred from the above. The "stream of consciousness" seems to be the play of perceptions in systems which are making adjustments, or, in other words, the focus of attention follows the largest-magnitude error signals anywhere in one's systems. When driving on the expressway, for instance, my attention, and thus my consciousness, can be on a chapter I plan to write, something I need to do when I get home, or the like; but let someone cut sharply in front of my car, and all that disappears, as the error signals in my driving program escalate in magnitude.

Is it different when I am not currently acting? When I am, for example, lying on a couch, just ruminating, as in Sigmund Freud's method of free association? As Freud pointed out 100 years ago, if one pays attention to the trend of such ruminating, an orderliness emerges which might not have been apparent at first. He suggested that the experiences coming to mind in those conditions often reflect unresolved conflicts in one's personality. I believe that is because the same processes are at work here which are at work in action, except when no current action in the environment is needed, the highest-order system begins to scan the principle level immediately below, monitoring for the source of errors disturbing the consistency or completeness of the self system.

The implication which I draw from the control-theory model is that the stream of consciousness one observes in "free association" might consist of switching back and forth while monitoring systems in which some chronic error signals need correcting. Systems on the level of principles or self, in which adjustments might be needed, become the subject of attention when one is not busy with ongoing programs, such as those of working, cooking, shopping, socializing, etc., possibly because preceding action programs resulted in unanticipated disturbance of some principles in the course of meeting the demands output by others (see the discussion of "virtual reference levels" in Powers, 1973a, p. 255).

"Free-association" ruminations might also include imaginary adjustments: random, vicarious trial and error speculation—action of the Reorganization System—in higher-level systems.[1] This would be what we call daydreaming or idle speculation, if after a "tryout" in imagination, we abandon it as not feasible for action; the same thing is called "planning" if we *do* carry it out in action.

Even when such ruminations seem preoccupied with memories, such memories often concern previous versions of chronically insoluble personal problems or recollection of earlier problem solutions (possibly) being tested for goodness of fit to current problems. The concepts of "wishful thinking," "fantasy," and "problem solving" seem to overlap at this point.

This series of speculations leads to a further one: "Will" is a term for naming the aspect of oneself which takes note of a change of reference signal—a new intention—transforming the ongoing course of action into a different one. However, the concepts defining the controlled perceptions of the different levels of the hierarchy, such as principle and program, have been defined only sketchily so far; therefore, we lack sharp criteria by which to distinguish the kind of "act of will" we term "changing my mind" from reference-signal shifts which modify a currently operating program too subtly to be experienced as fully changing one's mind. In fact, without definite criteria, it is hard to decide whether such a distinction is even really meaningful.

What we actually notice about what we are doing depends upon what we are paying attention to when a shift in reference signal happens to arrive at the on-going program. It also depends upon the nature of our personal program for creating meanings. How we describe to ourselves in thought what we believe about how we function is, itself, accomplished by a particular type of program—one which builds explanations—in this case, construction of one's theory of how one "works."[2]

That kind of program functions just the way any other program functions: with whatever repertoire of skills and concepts we have previously accumulated. Thus, it is not surprising that people can get into heated arguments about what sentences best describe such intricate observations as those relating to a person's view of the origin of his or her higher-level intentions. However, so long as we accept that "will" is a loose, roughly defined term, it can be a useful word to refer to those events in which a person takes note of becoming aware of a shift in higher-level output by perceiving the coming-into-being of a newly controlled perception, and attributes the agency of that shift to something in oneself.

One could even imagine catching B. F. Skinner in an unguarded moment with a question such as, "Which do you *want*, coffee or tea?" and having him react as if he found it a meaningful question. Then, if we asked him if that might be called an instance of his will in operation, he might grant it grudging affirmation (but, of course, adding that *we* understood it *wrong*).

This leads to the interesting question of how one might look at the problem of "free will versus determinism." I believe that there is an answer of sorts implicit in (at least one way of interpreting) Powers' model. All of the versions of "free will" which I have seen seem to involve either of two dilemmas. One is the dilemma created by Descartes: that the organism we see in the flesh is only a sort of vehicle for the real, that is, the spiritual, person, about whom we can never fully know. Will, in that view, inheres in the spiritual part of the person; we only see its effects upon the body as the individual turns from one activity to another. The opposite dilemma comes, I believe, from those who reject Descartes' conception. It results from postulating an internal, neural agency which stimulates the various reflexes, causing the activation of the body—the role Eccles assigned to thought—while failing to consider how the internal agency chooses what action to initiate. I can see only an infinite regress, such as one experiences from looking into the mirrors facing each other in a barber shop, in this "solution." It amounts to asserting that there is someone inside the someone inside the someone... ultimately deciding what to do at any moment. It evokes the question, "How does that final someone decide what to do?" If the answer is "at random," then that is *not* free will as it is usually understood. If the answer is "we don't know," it seems reasonable to ask a further question: "How do you know it is free?"

The only answer left would seem to be that "determinism" does not fit with peoples' experience. I would agree with that, but it is a very weak position, scientifically. On the other hand, to conclude that what seems like will must be the mechanical result of physical forces in the environment, would appear to demand a conception of physics to which most modern physicists seem unable to subscribe. There is no mechanical clockwork universe anymore, in which events happen with machine-like necessity.

We believe we observe ourselves choosing, but then who is it who observes that?

A tentative answer is that there is a semantic problem being overlooked in the above statement. Are we really aware of *choosing*? I don't think so. I believe we are aware of *having made a choice*, or of the perception which has been newly specified. I suspect that people always have inferred backward to think we were aware of choosing. In fact, as Goldstein noted in Chapter 14, when one experiments with Powers' Method of Relative Levels, one discovers that one monitors the perception controlled by a given system from the level above. Then, if there is a *highest* level, by definition there can be no level from which to observe it—at that point, you can become aware *only* that there is a part of you of which you can not become aware.

Therefore, the term "will" does not apply to phenomena of the highest order, although it might be referred to that level, in one's theory of oneself, by inference. We "live" most of the time, I believe, at the level of principles, from which we attend to, or monitor, our ongoing programs—our actions in the world. (And hence, we think we live in the world of action, because program-level perceptions are what principle systems monitor.)

So, when I *choose* to alter my current perception—which is the same as saying some program-level reference signal is altered by output from the next level above—that action is free *from the point of view of the level which monitors my consciousness*. It is free in that I experience my course of action as altered from somewhere inside myself, and even powerful environmental disturbances could not prevail against it—as in known instances where a mother held her baby high and out of harm's way while falling on her face on the ice, or a soldier chose to dive on exploding grenades. But what sends the reference signals to the level of principles, from whence the ongoing programs are monitored? That is an even higher level, and maybe all there is.

By definition, the highest level doesn't get reference signals from anywhere, thus one inference would be that it is in a state of reorganization (albeit, perhaps slowly and chronically) throughout life. In terms of the model, that means that random signals in the system-concept system occasionally adjust the setting of principles (or read values or attitudes) for no apparent reason. I find this speculation appealing, because it offers a way to account for the observations which I sometimes make of myself (and others to whom I am close) doing something "out of character," or not "being myself today."

If there is anything to this speculation, we can see that at the highest control level in a person, there is *neither* free will *nor* determinism, as those terms are usually used. The highest level perceives a "map," a theory or conception of reality *including one's self,* which may be chronically being altered (usually gradually) by random rearrangements, but at most given times is stable enough to output consistent reference signals to the level of principles. On the level of action, where one is usually conscious, the observation of making choices is validly assigned to oneself, because one can remember the immediately prior reference signal to a given program after it has been altered, and one can have at least a vague sense that the source of such shifts of intentions is also identified as oneself.

This gives rise to some further speculations, concerning the concepts of unconsciousness and preconsciousness made prominent by Freud. As a result of his practical work of psychoanalysis, Freud postulated that there are aspects of "mind" not ordinarily accessible to consciousness, but capable of becoming so: the preconscious. There are other aspects which he believed cannot be accessed: the unconscious. However, so far as I know, he did not offer a view as to why this is so. The idea of the connection between consciousness and attention developed above suggests some hypotheses concerning the underlying nature of the phenomena to which these terms refer.

That which is not present in, but accessible to, consciousness is the mass of all of the controlled perceptions to which one is not attending, because they are currently "on automatic." They are being controlled to minimum error, while the current reference values are being maintained. They emerge into focus when we attend to them: when they are coming to new values after receiving changed reference signals.

That which is never accessible to consciousness is the structure of the highest-order system. This might be the reason why people often engage in the kind of self-theory-building which goes on in intimate interactions of the type: "You are (so and so)," "I am (such and such) a person (do you agree?)" (cf. Epstein, 1973; Robertson, et al., 1987).

A final note, deriving from the view of the relationship between thought and action just discussed, offers a possible resolution of the perennial problem of attitudes and actions. Researchers interested in attitudes frequently puzzle over the connection between the verbal expression of attitudes and the actions which should be forthcoming from them—between what a person says he or she is going to do and what he or she actually does. Research attempts to clarify the relationship between when people's actions are consistent with their attitudes, and when they are not, are generally fraught with confusion and ambiguity. These research questions become fogged over because they harbor a hidden assumption, I believe, helping to create the problem. It is the assumption we noted above in the quote from Eccles: that thoughts produce actions (somehow). As long as one is making that assumption, it is an understandable mystery that attitudes (which presumably exist first as thoughts) are sometimes acted upon, sometimes not.

When we examine this issue through the lens of the control-theory model, thoughts and actions are *both* controlled perceptions—though involving different hierarchical levels. The critical consideration is the intention or purpose (the reference signal) behind the thought (the internal perception of an attitude or action goal), the verbal expression of an attitude, and the intention behind an action. Each of those words refers to a particular kind of program-level perception. But they involve *different* types of programs. The programs producing actions control sequences of physical events. The kind of program which produces the report (to an audience) of an attitude is one of stringing words together for the purpose of creating whatever effect the speaker wants to create in the listeners. One can express an attitude to convey information, project an image, influence a desired reaction, or formulate an ideal. One also can perform an action for any of these purposes, and more. But there is no necessity that the programs producing actions be consistent with those producing statements of attitudes, other than that required to meet demands for self-consistency, as discussed in Chapter 11.

The "person in the street" seems to have a grasp of this, as reflected by the aphorism "actions speak louder than words." Perhaps the layperson's understanding is better than that of the psychologists who try to study attitudes without taking into consideration the intentions behind a person's declarations. The layperson, unlike the psychologist, is not burdened with the idea that behavior must be examined without reference to one's purposes.

16.3 Speculations Concerning Transference, Stereotyping, and Scapegoating

These problems in human relationships typically are dealt with in textbook chapters on clinical and social psychology, but they actually combine processes from other traditional specialties, such as perception, cognition (categorizing), and social relations. Psychotherapists, especially, pay a good deal of attention to the process which Freud termed "transference," defining it as projection onto the therapist of attitudes which a client had developed earlier in life toward his or her original caregivers.

Since Freud was specifically interested in "transference" within the psychotherapy relationship, he did not discuss it as a feature widespread in social interactions in general. If he had had that perspective, he might have viewed transference as a special case of the general human phenomenon involved in projection, prejudice, and scapegoating. As soon as one turns to the questions of why these behaviors occur and how they work, it becomes apparent that they are related aspects of a general phenomenon. This has tended to be obscured, because the elements comprising the basic concept have been spread around in the various specialty subject areas mentioned above.

How might we define that general phenomenon within the control-theory model? We begin with the control of prinicple-level perceptions, especially those ordinarily called attitudes, considering the manner in which one has formed the perceptual categories with which the programs implementing one's attitudes work.

Following the kind of analysis proposed in Chapter 12 above, we first look at the phenomena in question from the highest-level output we can isolate. We need to look at what the person is doing, in the broadest sense. In the case of a client in a psychotherapy consultation, perceiving another person to whom he or she is trying to relate, the immediate controlled principle-level perception would concern "How do I relate to this person?" It is the first question in any human interaction, making appropriate allowances for the nature of the relationship in question. This occurred to Freud too, and he pointed out that the therapist's position, as viewed by the client, has many features in common with that of a (generic) parent. The client usually begins by looking to the therapist for orthogenic, developmental transactions: being given useful information, instruction, discipline, guidance and approval, not necessarily all at once. The client must begin interacting with his or her own version of how to relate to a person with whom he or she is looking for that kind of relationship. The way he or she relates will contain a projection of his or her categories for a person in that role, as well as his or her current repertoire of relationship activities "appropriate" to them.

One controls one's desired perceptions for relating in any other social role in the same manner, starting with category-level systems. In that sense, a degree of "transference" is involved in one's initial classification of one's counterpart in any new interaction. The extent to which another person may remain in the initial category, or eventually may be perceived via a different one, would depend on the functioning of all of the other systems in one's hierarchy. Likewise, the particular interaction program one employs in relating to the other person comes from reference signals in one's own repertoire of relating skills—the only place from which they *can* come. These reference signals were built up from storage of previous perceptions, going back through successive versions to the earliest ones of that particular type of control system.[3]

As in every situation, the program currently working must satisfy reference signals from as many principles as are acting upon it. In the psychotherapy example, the reference signals relating to "how to act" toward the therapist must be integrated with the kind of help the person wants, and with his or her definition of the problem. Furthermore, the goals of the client are affected at any given moment by all of the levels on which error signals are undergoing attempts at correction, and all that is finally under the control of the individual's system concept, defining what reality is, and who one is and wants to become. A similar description would apply, in a generic sense, to anyone relating to anyone else in any other kind of situation.

As you look at the above attempt to provide a verbal description of what is going on in a given moment in any kind of human interaction, you might feel that the description looks hopelessly complicated. But here it is important to distinguish between the verbal description of something and how it actually is controlled in a real-life situation. From the conception of consciousness developed above, we infer that one perception is being controlled at any given time, *and* that it contains all of the adjustments capable of being made just then. All else is occurring automatically, and the controlled perception matches a composite of all of the elements needing to be maintained simultaneously under control.

Keeping this point in mind, we can suggest a kind of generic analysis of projection, prejudice, stereotypy, and scapegoating: each of these involves a basically similar process of implementing the control of one's principle-level perceptions with programs which draw upon the individual's own peculiar distillation of past configurations, events, relationships, categories, and sequences.

The process might be viewed as beginning with the physical sight of the other person—at the configuration control level. But, as we noted in Chapter 10, the configuration itself comes under the control of one category or another. If the configuration is new, there may be some uncertainty, or ambiguity, in categorization. It is ultimately decided in terms of ongoing programs or principles, in which there may be a certain amount of chronic error seeking resolution. Even more ultimately, those levels are striving to satisfy reference values set by one's perception of the person whom one is. Therefore, we could see the perception of any new person as a combination of immediate signal interpretation (configuration control) and transference, since one only can interpret current configurations in terms of categories built up in one's prior experience. The next step in the sequence is projection, as one "fills out" the perception with elements inherent in the category elicited. Then, if one has error signals in one's sense of security, power, and so on, it opens the way for prejudice. And finally, if there are chronic error states in systems involving reactions against, or inhibiting, past aggressions, and if the dominant principle does not inhibit such expression at present, then it becomes an occasion of scapegoating. (In layman's terms: cases like yelling at one's spouse because of anger at one's boss, which was *not* acted on.)

The common element is to be seen by looking outward at the world from the individual's point of view, trying to glimpse the variables he or she is attempting to control with the transferential, stereotypical, scapegoating behavior in question. From the point of view of the person displaying such behavior, it does not merit those negative terms. It is simply the appropriate way to deal with the environmental situation as perceived. (A person may later have an insight that his or her perception was dominated by internal, imagined, rather than external, immediate elements, of course.)

When describing the process like this, we recognize that the layperson already has a reasonable interpretation of what is going on, when he or she says that people initally act toward others in terms of "who they remind you of," and with whatever repertoire one has built from past experience as relevant to the situation as one classifies it. But the control-theory model suggests one more element in the analysis, an element contained only vaguely in the "person on the street" explanation, and usually left out entirely in traditional psychological research on these topics. That is the definition of what the individual *intends* in the situation. Because all of the reference signals referred to in the above discussion are tied together—integrated—into one to-be-controlled perception by the individual's intentions of the moment, different persons can do what looks like the same thing for different reasons, and other people can do different things for what would seem the same reasons, in seemingly similar circumstances.[4]

Thus, the fact that terms like prejudice and scapegoating contain value judgments external to the persons to whom they are applied tends to segregate the behavior in question from the universal human activities of controlling one's experienced environment with one's existing control systems. This does not mean that I think nobody is ever unjust, unfair, unreasonable, or unrealistic, and never "takes out" on another person something he or she does not deserve. But these judgments are *external;* no one applies them to himself or herself, unless he or she has begun to form a negative self-image.

It would be an improvement in the analysis of transference and prejudice, then, to examine these social phenomena first of all in terms of the problem which is solved in the moment, by the behavior in question, for the person in question. In the broadest sense, that will turn out to be what *all* problems are in control-theory terms: indications of systems with chronic error signals. Thus, we can regard particular instances of the types of behavior we are discussing as examples of unsolved personal problems which the prejudicial behavior is taking the opportunity to solve.

Why it could be that a person with chronic error signals from previously inhibited intentions (for example, to respond aggressively to mistreatment) is inclined to seize a new, and possibly safer, opportunity to carry out such intentions appears to be almost a self-answering question in terms of the control-theory model: If there are chronic error signals from inhibited actions, the original "lockup" must have derived from competition between principle-level outputs (some to protect oneself from perceived threat or abuse, others also protecting oneself, but from the consequences of opposing potentially overwhelming odds). When those systems become activated in new circumstances, where the odds are changed, still other principles trigger the actions externally called scapegoating, etc. (This view is expanded by some of the speculations concerning the persistance of unresolved error signals in section 5, below.)

16.4 Speculations Concerning "Defensiveness" and "Resistance to Change"

When I was in graduate school, there was a great deal of interest in the Freudian concept of defensiveness. What forms did it take? How could one deal with it? How to distinguish when it was or was not justified? Among all of the questions, the one which seemed most important was the hardest to answer: where does it come from, why does it happen at all, and just what is being "defended" when one is being defensive?

When I finally obtained the answer that it is "the ego" which is being defended—against dissolution, coming apart—that was satisfying for a time, but then still one more question arose: why does the ego *need* to be defended against dissolution? The traditional answer went around in a circle. The ego is what holds the person's awareness-of-being-a-person together, as well as managing what one does. If the ego is overwhelmed, the person cannot act effectively, experiences unbearable anxiety, and may dissolve into either insanity or suicide. What could overwhelm the ego? Unbearable experiences. What makes experience unbearable? Overwhelming anxiety.

The control-theory answer might simply be saying something similar in different words. But I think it does more than that, by adding additional concepts. The ego, as Freud used it, was a term for a hypothetical "manager" inside a personality. In Powers' model, management takes place by the setting of reference signals at all levels below the highest. However, since the output of the highest level ultimately affects all of the others, it (the self system) most nearly resembles the ego of Freud. If the self system, then, is subject to energetic reorganization, say because of crises in the intrinsic system (discussed in Chapter 7), the consequence of reorganization will be random changes of reference signals to systems below. That will disturb controlled variables all down the line. Systems which had been functioning automatically and well will then go into error states. In Chapter 7, we proposed that the term "anxiety" refers to the subjective aspect of such experience. The experience of anxiety, being extremely uncomfortable, would have as a natural consequence attempts by the self system to re-stabilize, to get rid of it. One way to do that would be to emit reference signals assigning prior, and/or well-established, values to the level of principles. The result would be what we call "regression." In many circumstances, that amounts to what is otherwise called "resistance to change." From this perspective, resistance in therapy, defensiveness, and regression are all terms for special cases of the more generic "resistance to change."

This phenomenon is not limited to control levels which we usually refer to as the personality. Workers in remedial training, special education, and rehabilitation are familiar with it in difficulties encountered at levels from eye-hand coordination all the way up to personality characteristics. We observe it in efforts to encourage reorganization where self-images as "patients," "cripples," or other special roles have already begun to form. The underlying process is, I believe, that once a hierarchy has been organized in an individual, disturbances to the perceptual variables it controls are strongly resisted. Directions to control the same conditions with new perceptions would constitute such disturbances. Control works automatically. Even though the new values might be more functional from an exterior, conventional, point of view, they constitute disturbances to the ongoing control exercised by the functioning systems of a "self-as-handicapped" person.

Initially, I was prompted to this view by a lecture of Austin Riesen (cf. Riesen, 1961), in which he described his observations on raising kittens with blindfolds until they reached maturity, and found that they then could not be trained to "see" (that is, use their eyes functionally), even though the visual equipment was still intact. It seemed puzzling, at first, that they did not use their eyes to get around, once they were "available." I surmised that during development the cats had grown to use the typical guidance systems of the blind—auditory and tactile cues—to guide their movements, and that later attempts to get them to use visual cues for the same activities were dealt with as disturbances by the already functioning movement-control systems.

Riesen's lecture came together for me with experiences in working with individuals from remedial education and rehabilitation populations. It struck me that, once the members of such populations have formed system concepts of themselves as *special* (that is, "handicapped") persons, efforts to train them to be more "normal" would cause error signals in their existing control systems, just as seemed to have happened with Riesen's cats. I speculated that a similar explanation could account for the resistance to psychotherapy and remedial education which workers in those fields find so frustrating. (Robertson, 1966.)

From an external point of view, the handicapped seem to hang onto perceptual and learning handicaps stubbornly, while often declaring that they want to cooperate with those who are trying to help them. From an internal point of view, they are simply acting automatically and quite unconsciously to correct disturbances of ongoing controlled perceptions, as everyone does.

16.5 Why Do Emotional Traumas Persist in Their Impact?

Another phenomenon, familiar especially to psychotherapists, is that particularly powerful experiences are sometimes re-experienced with emotional concomitants which may not have been expressed in the original event. From this it has been inferred that the emotional reaction to powerful experiences might often, or regularly, not be experienced by some people. These unexpressed feelings and reactions are called *repressed*. A companion belief of many mental health professionals is that such repressed emotional reactions to traumatic events act like time bombs in one's experience, prone to be re-evoked repeatedly until recognized, expressed, released, and finally put to rest under therapeutic conditions.

If this is indeed a fact, why should it be? A possible answer, in line with the speculations above, is that starting when the reorganization system is operating, the circuitry existing when reorganization closes down consists of a composite of all of the systems acting in the event. That constitutes that system: the circuit which is retained. However, the form of organization solving some momentary problem may become the source of a different one. If, for example, a person has developed in such a way as to tense his or her body and hold in emotional expression under conditions of growing excitement, the reference signals of those principles will be part of the composite reference signal for the control of future perceptions from the same category. But this will itself become a source of chronic error signals in the systems which are thus set to block, or inhibit, each other. Then, if at a later time the same individual has organized some new systems, such as a principle like "belief in the value of emotional openness," certain aspects of the composite will be changed when that category is again evoked. This time, the "same" perception will be controlled to a different reference value, and the individual will display different behavior to an observer—who will see him or her as more expressive.

Although therapists cannot *cause* reorganization in a person, nor determine the form that it will take, they (or anyone else who has the subject's attention) can sometimes make a difference while reorganization is proceeding. If their words, gestures, and other forms of communication serve to "spotlight" an uncontrolled variable, bringing it to the attention of a person undergoing reorganization, it may make a critical difference (see Chapter 14). An individual also can do this for himself or herself, at times. It might occur randomly, or it might result from the activation of reference signals acquired since that particular category was last evoked. For instance, in listening to a number of different persons telling of a time when they gained a release from (or at least achieved significant progress with) personal phobias, I have noted at least one common element: each person's attention diverted from preoccupation with the symptoms of anxiety, to focus instead upon his or her goal in the situation. In such cases, the to-be-controlled perception gains a greater chance of being controlled, because the individual attends to components of the goal, rather than symptoms—just as a tennis stroke is more likely to be completed successfully if the player is attending to the point of contact between ball and racquet, rather than to some other perceptual variables. Then, as the desired state begins to be achieved, other systems "settle down," as they are now incurring fewer disturbances.

16.6 Conclusion

I hope that this chapter has given the reader an illustration of how the control-theory model can facilitate reexamination of chronic problems of basic theory, and can propose new ways to look at them. Whether the particular speculations offered ultimately will contribute to the growth of knowledge remains for the future to determine. It is my hope that they will encourage experimental testing and new theoretical formulations, and result in useful new applications. In any event, I would like to believe that the reader will take the new paradigm as a basis for tying together many disparate problems in previous psychological thinking, providing the impetus for new approaches and perspectives.

Notes

1. A suggestion of Powers, made at one of the Control Systems Group annual meetings. Compare also Rosalind Cartwright's view of the function of dreams (Lyon, 1990).

2. It is the kind of program in which someone, once upon a time, apparently needed a new term to refer to an observation which was hard to describe, a way to indicate an agency initiating action within oneself. Once the term had been coined, others also must have found it useful.

3. The debate among different schools of psychotherapy over the question of whether a person enacts his or her *earliest* or *most current* perceptions seems to me to be a false issue. If you examine the proposal in Powers' model for how reference signals are formed, it suggests that the earliest version of a control system becomes transformed as many times as it undergoes reorganization, but unless reorganization wipes out a particular circuit entirely, successive modifications will contain a kernel of the original version.

4. The external point of view, employed by researchers doing traditional social psychology experiments, made it easy to overlook the *foremost* perception any subject is controlling: the perception of who he or she is and what he or she is doing in the experimental setup. The traditional method aims to find facts about human nature, while unconsciously assuming the research subjects to have a "nature" possessing no intentions higher than those which the researchers want to study.

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