
Chapter 1: Experimentation In Psychological Research

[Comments added by your instructor appear in square brackets]

This initial chapter has two major aims. First, we shall locate experimental psychology within the context of psychological research in general. Second, we shall introduce and define a number of indispensable concepts; some of these concepts, which form a foundation for future developments, will be used to further the first aim.

**Psychological Research**

1. “Research” is a word much used these days but probably no longer conveys meaning of useful precision. It will be of some help in later discussions to make certain distinctions now among “research,” “experimentation,” and related terms.

2. We may include under the term “psychological research” all inquiries into problems within the sphere of psychology. Psychological research, in turn, may be subdivided into two distinguishable, though interrelated, categories: theoretical research and empirical research.

**Theoretical Research**

3. Theoretical research subsumes those inquiries which deal primarily with the development of theory in psychology. Such inquiries often take the form of (1) what may be called “library research” and (2) theory construction.

4. **Library Research.** In library research one attempts to integrate the findings or data in a particular problem area of psychology around a set of empirical principles or attempts to derive hidden generalizations from seemingly diverse data. Examples of such research are found in the frequent “review” articles that are published in the journal *Psychological Bulletin*. In these articles the accumulated research in a circumscribed problem area of psychology is examined in detail, and an attempt is made to glean generalizations or formulate hypotheses from the data which help one organize and understand them. Thus some theory construction, limited in depth and scope, is often involved in library research.

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1. [See Review of Educational Research for integrative review articles of educational topics.]
5 **Theory Construction.** The development in psychology of systematic theories does not, of course, occur in isolation from empirical research; rather, theory construction and empirical research are complementary activities. One may nevertheless distinguish activities that are primarily theoretical in nature; the goal of these is the elaboration of a theoretical structure which will account for a substantial body of data. Such theories may be informal, stated completely in verbal terms with no attempt at rigorous definition of the basic theoretical concepts and their interrelations, or, much less frequently in psychology, they may be quite rigorously developed. Psychoanalytic theories, for example, generally fall into the former category. A classic example of the latter type of theories may be found in the rather formidable *Mathematico-Deductive Theory of Rote Learning* by Hull and others (1940) and in Hull's later, more manageable *Principles of Behavior* (1943). More recently, psychology has seen the development of thoroughly mathematical theories, as in the field of learning (e.g., Estes, 1959). This new approach quickly built up the momentum to justify the launching of the three-volume Handbook of *Mathematical Psychology* in 1963 (Luce, Bush, & Galanter, 1963, 1965) and the inauguration of the *Journal of Mathematical Psychology* in 1964. However, rigorous quantitative models need not be cast in mathematical terms; information-processing models in the form of computer simulation programs have also been used to achieve these ends (cf. Gregg & Simon, 1967). 1

6 **Empirical Research**

6 Within empirical research we can distinguish three general and closely related research approaches: (1) observation (in a natural or in a laboratory setting), (2) correlational research, and (3) experimentation. A large portion of this chapter will be devoted to a discussion of these research approaches. 2

7 **Observation.** The antiquity and power of observation as a research method are illustrated by the fact that astronomy, the oldest and one of the most precise of sciences, was founded by inquisitive man with little more than his curiosity and his eyes. This is not to say that observation alone can sustain the development of a science; at the very minimum, correlational research is a necessary accompaniment. But observation is very often the source of interesting and important problems as well as the origin of the hypotheses leading to their solution.

8 Strictly speaking, observation involves the noting and recording or events without formal manipulation of variables operating in the events under study. To illustrate within a hypothetical situation, suppose that a

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2. [The type of approach limits the kind of statements that can be justified. The observation approach permits the investigator to make descriptive statements but not objective statements about relationships between variables, nor statements about cause-and-effect relationships. Observational approaches, whether in natural (aka “field”) or laboratory settings, allow only descriptive statements. Such statements may be long, narrative summaries, replete with the “thick description” valued by qualitative investigators, or they may be numerical summaries (aka “descriptive statistics”) based on responses to a survey. Regardless, the observational (aka “descriptive”) approaches do not enable the investigator to make objective statements about relationships that may exist between variables, nor to make inferences about causal relationships. (See Miller, Steven I. & Fredericks, Marcel (1994). *Qualitative research methods: Social epistemology and practical inquiry.* New York: Peter Lang. Miller and Fredericks explain in detail why inference making cannot be justified for observational/descriptive approaches. This includes all qualitative approaches favored by anthropologists and ethnologists. For a succinct treatment, see the review of Miller and Fredericks book: McLean, Les, Myers, Margaret, Smillie, Carol, & Vaillancourt, Dale. (1997). *Qualitative Research Methods: An essay review. On-Line at http://olam.ed.asu.edu/epaa/v5n13/).*]
researcher wishing to learn something about group processes in children observes a group of children in
schoolyard play. From his observations he might arrive at the hypothesis that individual aggressiveness
and group leadership are positively related; that is, the more aggressive children tend to engage in group
leadership behavior more frequently than the less aggressive children. Thus far, the research, involving no
formally manipulated variables, may be classified as observation.

9 Going further, the researcher, as a first step in the verification of his hypothesis, would obtain some mea-
sure of the aggressiveness of an individual child, either by means of an appropriate psychological test or by
a rating procedure. On the basis of such a measure, he very likely would select for particular attention in
future observations those children scoring high and those scoring low on aggressiveness. And if his
hypothesis were correct, the former should engage more often in group leadership behavior than the lat-
ter. We may consider the psychological test, or the rating procedure, to constitute a means of “manipulat-
ing,” through selection, the variable of aggressiveness. Thus the researcher, in manipulating this variable
and relating it to another variable, group leadership, is no longer engaged in observation only, but rather
has advanced to what is called “correlational research.”

10 When observation is employed on events in their natural setting, we speak of natural observation. Our
researcher, in his study of the children, was initially involved in natural observation. Many studies in ani-
mal behavior are grounded in natural observation, as are a good many sociological and anthropological
researches.

11 However, where feasible, natural observation often gives way, to laboratory observation. The reasons are
simple. Control over relevant factors is more practicable in a laboratory setting. Phenomena observed
under natural conditions are constantly subjected to the operation of factors which the researcher cannot
control and which might greatly complicate the events under observation. Further, in natural observation
one must seek out or await the events he wishes to observe, whereas, on the other hand, in laboratory
observation it is often possible to initiate the events of interest through manipulation of environmental
and related factors.

12 Correlational Research. A very important segment of psychological research makes use of correlational
techniques. Cronbach (1957), dividing scientific psychology [in contrast to clinical psychology] into
experimental and correlational psychology, includes in the latter such areas as construction and applica-
tion of psychological tests, differential and developmental psychology, and some instances of comparative
psychology. An important defining feature of correlational research is that the variables under study are not
directly (experimentally) manipulated by the researcher. Rather, variation in the variables of interest is
achieved by some sort of selection procedure. In psychology, selection procedures often take the form of psy-
chological tests [italics added]. Thus, if one were interested in the relationship between intelligence and
problem-solving ability, the variable of intelligence would be manipulated by using some reasonable test
of intelligence to select out individuals of different levels of intelligence. Quite clearly the researcher could
not directly (experimentally) manipulate intelligence in his subjects. He could not convert one group of
subjects into highly intelligent individuals and a second group into subnormally intelligent individuals.
Special aptitudes and many personality variables are other examples of classes of variables that can be
manipulated by the researcher only through selection procedures.

1. [The characteristics that distinguish correlational research from observational: In correlational
research the investigator selects particular variables, measures them (psychological test and/or rating
scale) and tests to see if a relationship exists. The methods used for measurement and testing are public
and therefore replicable by a critic. Methods and/or procedures that are public are said to be “objec-
tive.” In observational approaches, the investigator does not begin with variables (“themes” are said to
“emerge”), independent variables do not exist, the methods are not public, and thus not objective.]
The advance of correlational research over observation lies in the focusing of interest on specific aspects (variables) of the phenomena under study. The question asked in this kind of research is: Are variables A and B related, and if so, how? Answers to such questions require means of measuring A and B and methods of manipulating A or B or both. By manipulating A we mean arranging for different quantities or different values of A to appear. As previously stated, correlational research is characterized mainly by the way variables are manipulated, which is never directly, as in experimentation, but rather through a selection procedure. Thus, if we wish to manipulate (arrange for different quantities of) scholastic aptitude, we cannot do so directly. We cannot with any means at our disposal — drugs, training techniques, or surgical intervention — establish at will in an individual an arbitrary level of scholastic aptitude. We can only, through the use of some indicator of scholastic aptitude, choose or select among individuals in whom differences with respect to this variable already exist. As a general statement, we may say that research is likely to be correlational in nature whenever all the variables under study concern properties of the subject which are either inherent to the subject (e.g., age, sex, phylogenetic level) or are the result — wholly or in part — of prolonged experience (e.g., aspects of personality) [italics added].

Although correlational research often suffers certain limitations, particularly with respect to controlling relevant variables and rendering conclusions concerning cause-and-effect relations, important areas of investigation exist where its use is unavoidable. Further, in the hands of an able researcher, the advanced statistical tools (factor analysis, for example) developed in some areas of correlational research can prove to be powerful instruments in the dissection and analysis of complex phenomena, such as human intelligence (Guilford, 1959, 1966).

Cronbach, himself an arch-correlational psychologist, said this about the potentialities of correlational research:

The well-known virtue of the experimental method is that it brings situational variables under tight control. It thus permits rigorous tests of hypotheses and confident statements about causation. The correlational method, for its part, can study what man has not learned to control or can never hope to control. Nature has been experimenting since the beginning of time, with a boldness and complexity far beyond the resources of science. The correlator's mission is to observe and organize the data from Nature's experiments. As a minimum outcome, such correlations improve immediate decisions and guide experimentation. At the best, a Newton, a Lyell, or a Darwin can align the correlations into a substantial theory (Cronbach, 1957, p. 672).

Cronbach and others (e.g., Gulliksen, 1968; Owens, 1968) have urged that experimental and correlational techniques be combined to form a powerful attack on difficult research problems. As yet, however, these suggestions seem not to have been heeded widely by experimental psychologists.

In summary, correlational research, unlike observation, involves the manipulation of specific variables chosen from the area of research interest. Manipulating a variable means arranging for the appearance of different quantities or different values of the variable. In correlational research the manipulation is always accomplished by some sort of selection procedure.

**Experimentation.** The sine qua non of most sciences, including psychology, is experimentation. Even astronomy, which relies heavily on correlational research, owes much of its viability to the improvement in observational techniques and apparatus constantly emerging from experimentation in allied sciences. In an ideal experiment, the investigator controls and directly manipulates the important variables of interest to him. Through careful manipulation of variables, the experimenter is able to show that changes in A result

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1. [Re-read this paragraph and note the distinctive features of correlational research: variables are identified, variables are measured via a psychological (cognitive or affective) test, and subjects are selected on the basis of their score on the cognitive/affective instrument].

2. [an essential condition; indispensable thing; absolute prerequisite].
in (cause) changes in B: mere concomitance is replaced by cause-and-effect relations. Because the variables with which the experimenter deals are usually within his province of direct manipulation, he is able to achieve a measure of control over relevant experimental factors not easily obtained otherwise, a control which enables him to untangle and isolate from nature's complexity the particular effects of specific variables [italics added].

19 The major criterion, then, for experimentation is that the variables of interest are subject to direct manipulation, as contrasted with manipulation through selection procedures. A few examples of variables that allow for direct manipulation may be cited from psychology; in fact, most variables relating to the experimental situation and to the experimental task are of this nature — for example, temperature, humidity, lighting, task instructions, materials, and procedures. Many “subject variables” also permit direct manipulation, such as anxiety level (when manipulated through the application of such aversive stimuli as shock), hunger and thirst drives, states induced through the use of drugs, and variations in (limited) previous experience brought about by different training procedures.

20 The distinction between direct manipulation of variables and manipulation through selection procedures is important for several reasons. First, when a variable is manipulated through selection, often other, possibly quite relevant, variables are concomitantly manipulated with the variable of interest. Such concomitant manipulation of variables can lead to very misleading interpretations of research results, as illustrated by the following example. Suppose a researcher interested in the relationship between height and amount of food intake initiates a study comparing the food intake of people of various heights. He would undoubtedly find that the two variables are positively related; that is, taller people eat more than shorter people. Although this empirically obtained result may be unassailable, would the researcher be correct in concluding that there was something about height itself that influences the amount eaten? Consider, for example, the hypothesis that in taller people the heart must work harder to pump the blood into the head region and that this added work expends extra energy, requiring, in turn, greater food intake. A little thought will make it clear that probably height is not the important relevant variable. The relationship obtained by the researcher most likely results from the close relationship of height and weight. In manipulating height, through selection of individuals of different heights, the researcher concomitantly manipulated weight, because taller people tend to weigh more. Thus, the tall people were not only taller than the short people, but they also weighed more—and it is quite likely that the latter variable is the important one. This conclusion, it may be noted, could be checked by measuring the food intake of one group of individuals who vary in height but not in weight and of a second group who vary in weight but not in height [italics added].

21 Of course, the danger of erroneous conclusions in matters of interpretation arises primarily when the concomitantly manipulated variable is subtle and goes unnoticed by the researcher—not an uncommon occurrence. For this reason, as well as others, it is often difficult in correlational research to make confident statements concerning cause-and-effect relations. To illustrate, a major reason for the widespread controversy concerning the causal connection between smoking and lung cancer may be traced to the correlational nature of most of the pertinent research. On the other hand, with direct manipulation of variables there is inherently much less of a problem with concomitant manipulation which, when it occurs in conjunction with direct manipulation, is generally more easily detected and eliminated [italics added].

22 A second reason for distinguishing between direct manipulation and manipulation through selection relates to the precision of manipulation attained by the two methods. Although with some variables manipulation through selection is very precise, with others a considerable margin of error is involved [italics added].

23 By “error” we refer to the discrepancy between the value of the variable assumed to have been obtained by manipulation and its actual or “true” value. Thus, any error committed in manipulating age as a variable
is likely to be small, but *this is not true for variables emanating from research dealing with aptitudes, intellectual ability, and personality. It is generally true, by way of contrast, that directly manipulated variables are normally subject to very little error in their manipulation* [italics added].

24 The *third difference* between the two methods of manipulation is that certain powerful research techniques, developed with directly manipulated variables, are inapplicable to most variables manipulated by selection procedures. Among the more important of these is the *single-group or within-subjects design*, a technique in which each subject serves as his own control. For present purposes we shall define single-group (within-subjects) designs as the method in which a single group of subjects serves under all conditions of the research. For example, suppose we want to determine whether nicotine has a deleterious effect on motor coordination. One powerful means of attacking this problem is as follows. We would choose a group of subjects and submit them to a series of motor coordination tests, one test daily. Before some of the tests the subjects would be given a dose of nicotine, and before others they would receive a placebo, an innocuous substance administered in the same way as the drug in order to control for suggestion. Hence, all subjects are tested under both the drug and no-drug conditions. If the drug has a harmful effect on motor coordination, we should observe that, in general, the performance of our subjects is poorer when tested under the drug than when tested after receiving the placebo. Note that because each subject is tested under both conditions, we need not concern ourselves with individual differences in motor-coordination ability [italics added].

25 Now imagine that the only way in which we could obtain subjects with different amounts of nicotine in them was to choose smokers and nonsmokers from the general population. In this instance we would be forced to use a *separate-groups (or between-subjects) design*; that is, one group of subjects (smokers) would be tested under the drug condition, and a second group of subjects (nonsmokers) would be tested under the no-drug condition. More generally, with separate-groups (between-subjects) designs, a separate group of subjects serves under each of the conditions of the research. By comparing the performance of the two groups of subjects, we can evaluate the effect of nicotine on motor coordination. Note that the situation with respect to individual differences in motor-coordination ability is radically changed. We are now vitally interested in any dimension of individual differences that might significantly affect motor coordination, such as age, sex, and occupation. Obviously we would want the smokers (drug group) and nonsmokers (no-drug group) to be well equated with respect to such individual characteristics. However, such precautions are not necessary with a single-group design because every subject is tested under all conditions of the research [italics added].

26 In summary, the cardinal feature of experimentation is that the variables under study are directly manipulated by the researcher. And it may be stated as a general principle that the more directly the researcher can manipulate his variables of interest, the more reliable and precise his results are likely to be. *Direct manipulation of variables possesses several advantages over manipulation by selection: (1) The dangers of concomitant manipulation of relevant but extraneous variables are considerably less potent with direct manipulation; (2) there is generally less error of manipulation involved when variables are directly manipulated; and (3) certain powerful research techniques, such as single-group designs, are possible with many variables that are manipulated directly but are possible with few variables that are manipulated by selection. In single-group (within-subjects) designs, a single group of subjects serves in all conditions of the research; in separate-groups (between-subjects) designs, a separate group of subjects serves under each of the conditions of the research* [italics added].

27 The progress from natural observation to laboratory experimentation is characterized by the researcher’s winning increasing control over the events with which he is concerned. Experimentation, however, is not limited to a laboratory setting; it is, in some disciplines, most often practiced within a natural setting. Similarly, correlational research may be conducted within a laboratory or natural setting. It will be possi-
able to make more precise statements about these interrelationships after we have introduced the concepts of independent and dependent variables later in this chapter.

**Psychology and the Concept of Variables**

28 Consider the following experiment. A subject (S)\(^1\) is seated before a table on which appear a small telegraph key and, next to it, a white electric light bulb. The S is fitted with earphones and instructed by the experimenter (E) to press the telegraph key as quickly as possible whenever he sees the white light illuminate or hears a tone through the earphones. The stimuli, the white light and the tone, are presented individually in an irregular order so that S cannot predict whether the next stimulus will be the light or the tone. During each stimulus presentation, E accurately measures S’s reaction time (RT), that is, the time elapsing between the onset of the stimulus and the time S presses the telegraph key. After 50 presentations of each stimulus, the experimental session is terminated.

29 Although relatively simple, the preceding situation contains many of the important features common to most experiments in psychological research. *Our present interest is the concept of variables, in particular independent variables, dependent variables, and relevant variables* [italics added].

30 Before proceeding, however, we shall state more explicitly what is meant by the term variable, namely, *any measurable attribute of objects, things, or beings*. The term has a very wide application, but it is not all-inclusive. For example, extrasensory perception is thought by some to be an attribute of human beings, but as it is apparently incapable of reliable measurement (cf. Hansel, 1966), we would not call it a variable. The measurability required of an attribute need not be quantitative. Race, sex, and religion, for example, are variables that are only “qualitatively” measurable. Later in this chapter we will return to a discussion of quantitative and qualitative variables [italics added].

**Independent Variables**

31 It may be apparent in the illustrative reaction-time experiment that E’s interest lies in determining whether the type of stimulus employed, tone or light, has an effect on S’s reaction time. The experimental question being asked is: Does, in general, an individual’s RT depend on whether the stimulus used is a tone or a light? To answer this question, E systematically manipulates the stimulus presented to S and observes whether S’s RT is faster with the light or the tone. Because the type of stimulus employed (tone or light) is a variable manipulated by E in order to determine the effects on the aspect of S’s behavior in which E is interested (in this case S’s RT), it is called an “independent variable.”

32 Note that in the present case E is able to manipulate directly the type of stimulus, tone or light, presented to S. However, E may deal with independent variables that he can manipulate only through a selection procedure. As an illustration, suppose E wished to investigate the question, Does the RT of an individual depend on his age? In order to manipulate the variable of interest—age—E would of course select Ss on the basis of their ages, obtaining representation from perhaps 20 to 40 years of age. Age, or more precisely S’s age, is a variable manipulated by E by means of selection in order to determine the effects on S’s reaction time; it is therefore an independent variable.

33 In general, then, an independent variable is any variable manipulated by E, either directly or through selection, in order to determine its effects on a behavioral measure (dependent variable).

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1. Indeed, a recent volume has been dedicated to the view that naturalistic research “... is the only appropriate or suitable way to answer some investigative questions and to fulfill certain investigative purposes [Willems & Raush, 1969, p. 3].”

1. Symbols introduced in the text are defined in Symbols and Abbreviations.
Because the method of manipulation is, as we have seen, of considerable significance, we want to distinguish between independent variables that are directly manipulated and those that are manipulated through selection. We shall refer to the former as “type-E” (manipulated directly or experimentally) independent variables; those manipulated through a selection procedure we shall refer to as “type-S” independent variables.

**Dependent Variables**

Any measured behavioral variable of interest in a psychological investigation is called a “dependent variable.” In our illustrative experiment, for example, it is clear that S’s reaction time is the behavior of interest to E and is subjected to measurement by the latter. Thus, the S’s RT is a dependent variable [italics added].

The requirement that a dependent variable be a behavioral variable is simply recognition that in psychological research the investigator is always interested in some aspect of the behavior of a living organism. However, the term “behavior” is meant to apply in its most general sense and includes not only overt, directly observable responses, such as reaction time and choice behavior, but also language responses—from which we may infer facts concerning perception, imagery, and similar phenomena—and relevant physiological reactions, such as pulse rate and the galvanic skin response.

By saying that the measured behavioral variable is “of interest” to E, we mean, more exactly, that E’s concern is in observing the effects of manipulation of the independent variable on the measured behavioral variable. The reason for this requirement is that we do not wish to include as dependent variables all measured behavioral variables.

In summary, a dependent variable is any behavioral variable measured by E to assess the effects of a manipulated (independent) variable.

**Interdependence of Independent and Dependent Variables**

It is clear from the definitions of independent and dependent variables that neither concept is defined independently of the other. One might surmise, therefore, that in the absence of specification of the dependent variable it would not be possible to identify positively the independent variable and vice versa. However, in all but the most poorly conceived research there is little doubt as to the identity of the independent and dependent variables.

There is, on the other hand, good reason for the interdependence of the two definitions. With independent variables, E often manipulates certain variables solely for the purpose of control, i.e., to eliminate differential effects of the variables from the research results. In such cases E is not at all directly interested in the effects of the manipulated variables on the dependent variable. In our illustrative reaction-time experiment, E manipulated the stimulus sequence, that is, the order of presentation of the light and tone. As indicated in the description of the experiment, E presented the stimuli in an irregular order until 50 presentations of each stimulus were completed. Suppose E first presented the tone on trials 1 to 50 and then the light on trials 51 to 100, adopting this procedure with all Ss. If it turned out that in general S’s RT to the light was faster than to the tone, could this result confidently be attributed to differences in the stimuli themselves? Could not the differences in RT be assigned as well to the fact that all 50 trials with the light as stimulus came after the 50 tone trials and, therefore, had the benefit of any practice effects which might have accumulated over the 50 tone trials? In other terms, had the light stimulus been employed on all 100 trials, it is quite likely that the RT on the last 50 trials would have been faster than the RT on the first 50 trials, simply because of practice effects. “Order of stimulus presentation,” then, is a variable manipulated directly by E to control its effects on the experimental results but not to determine its influence on the dependent variable; hence, it is not an independent variable.
The necessity of controlling variables — often through direct manipulation — that might obscure interpretation of the experimental results is an aspect of paramount importance in experimental psychology and will receive detailed treatment later. It is sufficient for present purposes to note that a variable manipulated by E is not classified as an independent variable unless manipulation is for the purpose of observing its effects on the dependent variable.

A complementary situation exists for measured behavioral variables. It sometimes occurs that E will carefully measure a behavioral variable for the one reason of using the data thus obtained for control purposes, for example, to equate groups of subjects for certain characteristics. To illustrate, suppose E wished to determine the effects on the retention of task A of learning task B, the latter task being learned after task A was acquired. One group of Ss, call it the experimental group, would learn task A, then learn B, and finally be tested on the retention of task A. A second group of Ss, the control group, would also learn task A and, perhaps after a short rest period, be tested on retention of A. The effect of learning task B on the retention of task A would be revealed by comparing the retention scores of the experimental and control groups. Because, in general, the amount retained by an individual might vary with the speed with which the individual learned the material, E would want to have the experimental and control groups fairly equal with respect to the speed of learning task A. One simple way of accomplishing this is for E to assign the Ss to the two groups after all Ss learned task A. He could then assign Ss to the experimental and control groups taking into consideration each S’s speed of learning task A.1, 2

It is clear that speed of learning task A is a measured behavioral variable, but it is also clear that E is not directly concerned with its effect on the dependent variable, retention of task A. Thus, it is not a dependent variable.

Relevant Variables

We have already seen that variables other than the independent variable can exert an effect on the dependent variable. To return to the reaction-time experiment, there are a number of variables, other than order of presentation of the stimuli, whose variation could be expected to affect RT. Intensity of the tone and light stimuli, force required to close the telegraph key, and location of the visual stimulus in the visual field are but a few such variables. However, there are innumerable variables, such as atmospheric pressure and S’s income and religion, that within wide limits of variation have no discernible effect on RT.

The class of variables that have an effect on the dependent variable are called “relevant variables.” The class that have no discernible effect on the dependent variable are called “irrelevant variables.” The purpose of much psychological research can be described as the classification of independent variables as either relevant or irrelevant variables. The question asked in the reaction-time experiment, for example, could be stated as: Is the type of stimulus, tone or light, a relevant variable with respect to RT?

We may now state one of the most critical tasks facing E: the identification and control of all relevant variables operating in the research situation. This is a challenging and difficult task whose accomplishment in psychological research is usually, to a greater or lesser degree, only approached. The identification and

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1. The terms “experimental group” and “control group” are commonly employed in psychology and related sciences; they are especially applicable to separate-groups-design experiments involving a single independent variable. If in such experiments one group of Ss serves under zero amount of the independent variable or under a value that is in some sense, a standard value, it is called the “control group”; the other groups are referred to as “experimental groups.” Thus in an experiment involving a drug and a no-drug group, the former is the experimental group and the latter the control group.

2. [The preferred term today for “control group” is “comparison group.”]
control of relevant variables are topics which receive repeated emphasis in a course in experimental psychology, and, in the present text, they will receive their fair share of attention. A detailed treatment of the historical aspect of this general topic has been presented by Boring (1954).

Interrelations among Research Approaches, Type of Independent Variables, and Research Settings

47 Now that the concepts of independent and dependent variables have been introduced, we return to a more detailed discussion of the three research approaches: observation, correlational research, and experimentation.

48 Table 1-1 summarizes the results of classifying the three research approaches in terms of the location in which the research takes place (in a natural or laboratory setting) and the type of independent variables employed (type-E, type-S, or none). It should be made clear that dichotomizing all research locations into two categories is for purposes of simplicity and is not meant to imply that all laboratory settings permit equally rigorous control over the research being performed. However, once external controls or constraints are brought to bear on the events one is studying, one is no longer conducting research in a natural setting, though the nature of the controls may vary enormously in their extent and in the degree of their rigorousness. Although the dimension of research location could, as indicated, be more faithfully represented by a series of categories rather than only two, the simplification imposed by the dichotomy will not invalidate our conclusions.

Table 1. Classification of Research Approaches by Research Location and Type of Independent Variables Employed

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<thead>
<tr>
<th>Independent Variables</th>
<th>Natural Setting</th>
<th>Laboratory Setting</th>
</tr>
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<tbody>
<tr>
<td>(1) At least one type E</td>
<td>Experimentation</td>
<td>Experimentation</td>
</tr>
<tr>
<td>(2) All type S</td>
<td>Correlational research</td>
<td>Experimentation or correlational research</td>
</tr>
<tr>
<td>(3) None</td>
<td>Natural observation</td>
<td>Laboratory observation</td>
</tr>
</tbody>
</table>

50 Numerous examples of the latter may be furnished from ethology which, like comparative psychology, deals with the objective study of animal behavior. In the following illustration, Tinbergen, the well-known ethologist, investigated the development of brooding behavior in herring gulls by directly manipulating the time at which (artificial) eggs were available to the gulls. However, as so often happens in science, his experiment provided information about an entirely different problem:

51 Herring-gulls... show a special reaction to food that is too hard to be crushed with the bill; they take it up into the air and drop it. An accident showed us that hardness is the property that releases the reaction in herring-gulls. In order to study the maturation of the incubation drive, I put a wooden egg on the territory of a gull before it had any eggs of its own. Until very shortly before the eggs were laid, the wooden egg did not release brooding behavior,
However, in some cases it released feeding responses, and once I observed that a gull, after giving a vigorous peck at the egg, at once took it in its bill, flew up in the characteristic way so commonly observed on the beach, and dropped the egg from a height of about 10 yards. .
. (Tinbergen, 1951, pp. 160-161).

52 A second illustration is taken from psychological research. The general research question was: Are IQ scores of children affected by prenatal nutritional factors? A study several years ago (Harrell, Woodyard, & Gates, 1955) attacked this question by directly manipulating vitamin supplements in the diets of several hundred pregnant women from low-income groups. Four comparable groups of pregnant women were chosen from a maternity clinic in Norfolk, Virginia. Three of the groups had their regular diets supplemented with vitamin pellets (vitamin C, B-1, or B-complex). The fourth group received pellets containing an inert substance (placebos).

53 Apart from the contents of the pellets, the women received similar treatment, and in their periodic visits to the clinic for routine examinations, they replenished their supply of pellets. When about three years of age, the offspring of these mothers were tested with the Stanford-Binet Intelligence Scale, and a small but highly reliable difference in IQ scores was observed in favor of the children whose mothers had, during pregnancy, received vitamin supplements.

54 Furthermore, as shown by later testing, this difference in IQ scores was still present at 4 years of age. (A second part of the experiment suggests, however, that such vitamin supplementation has no effect on IQ scores when prenatal diet is naturally adequate.)

55 It will be noted that in both the preceding examples a type-E independent variable was manipulated — presence of the wooden eggs in the gull’s territory and vitamin supplementation of the pregnant women’s diets — and the research took place under natural conditions — the herring gulls were not interfered with and the pregnant women’s behavior was not modified apart from ingestion of the pellets.

56 Turning now to research performed in a laboratory situation, it hardly seems necessary to present illustrations of experimentation that result from the use of type-E independent variables in a laboratory setting. For most people this sort of research is the very essence of experimentation. Although the bulk of experimentation probably takes place under such conditions, it should be remembered that important experimental research occurs outside the type-E independent variable-laboratory setting combination.

Research Employing No Independent Variables

57 Skipping now to the third row of Table 1-1, we see it is clearly possible for research to involve no formally manipulated variables, that is, to involve no independent variables. Such is the case of the researcher who, interested in the mating behavior of gulls, observes them from a distance by the hour in the hope of snatching clues to the important factors underlying their behavior. Such also was the case with our hypothetical researcher who was interested in group leadership behavior of young children (before he introduced an independent variable). Thus we may succinctly define observation as research activity that involves no independent variables. Observation often serves as a means of detecting promising relevant variables; the next step is the manipulation of these variables, which, depending on the nature of the manipulation, carries the researcher into correlational research or experimentation. Although observation is often identified with research in a natural setting, it is frequently encountered in a laboratory setting and is then called "laboratory observation."
Research Employing All Type-S Independent Variables

58 **In a natural setting.** When research employs only type-S independent variables (Table 1-1, second row) and occurs in a natural setting, we classify it as “correlational research.” Consider the following research problems:

1. Investigation of the relationship between high school grade averages and scholastic achievement in college
2. Evaluation of the relationship between incidence of schizophrenia in parents and in their offspring
3. Investigation of the relationship between season of the year and incidence of juvenile delinquency

59 In these examples the independent variables (high school grade average, incidence of schizophrenia in parents, and season of the year) are manipulated through selection, and the research takes place in a natural setting, unrestricted by the researcher. We therefore classify these studies as correlational research. As indicated by the independent variable of the third example (season of the year), type-S independent variables can be variables other than those relating to the subjects of the research, though in psychology they are most often “subject variables.”

60 A special case. A special case of research which employs only type-S independent variables merits our attention. Consider the question, Do people who rate high in “mathematical ability” also tend to rate high in “verbal ability”? To obtain data relevant to this question, one would secure a group of representative subjects and submit each subject to a reasonable test of mathematical ability and to one of verbal ability. If there were a positive relationship between the two variables, people who scored high on one test would, in general, score high on the other, and those who scored low on one test would tend to score low on the other. Now how shall we classify this research? It certainly is not observation, because two variables, mathematical and verbal ability, are manipulated through selection procedures (the psychological tests). But which one is the independent variable and which one is the dependent variable? Certainly, mathematical ability could be the independent variable in that the researcher might be interested in observing what happens to verbal ability as mathematical ability is manipulated, as, for example, if the researcher, given the mathematical ability scores of individuals, wished to predict their verbal ability. In this case, verbal ability qualifies as the dependent variable, and our definitions are satisfied. But the researcher could just as well be interested in the reverse situation, observing changes in mathematical ability that result from manipulation of verbal ability. With the roles of the two variables reversed, verbal ability and mathematical ability now fulfill our definitions of independent and dependent variables, respectively. We are forced to the conclusion that in certain situations, including the present one, the same variable can serve with equal rationality as an independent or a dependent variable, its role determined by the researcher’s point of view. The principle may be stated that **all research involving only variables that qualify with equal appropriateness both as independent and dependent variables is classified as correlational research.** As a matter of fact, correlational research is identified by some with only this last class of research, but as we have seen, it has a much more general application.

61 Note that in the earlier illustrations duality in the roles of the variables was not a problem; e.g., high school grade average, incidence of schizophrenia in parents, and season of the year do not qualify as dependent variables.

62 **In a laboratory setting.** We now arrive at the one set of circumstances where classification is equivocal: namely, where the research employs only type-S independent variables and takes place in a laboratory setting (Table 1.1, second row). The problem may be highlighted by an example.

63 Using a highly controlled laboratory situation, D’Amato and Jagoda (1960) studied how simple discrimination learning in rats was affected by three independent variables: age, sex, and rearing conditions. Each animal was reared from weaning either alone or with a single cage-mate. Now, age and sex are clearly
type-S independent variables, but because of the third variable, which was manipulated directly, we would classify the research as experimentation. However, suppose that the third variable had not been included in the study. The research would have then involved type-S independent variables alone. Still it would seem quite arbitrary and artificial to classify this study as correlational research, in view of the fact that intuitively the research retains much of its “experimental” character, even after deletion of the one type-E independent variable. There are two reasons for our intuitive preference to classify this study as experimentation rather than correlational research. First, the research setting is a highly controlled laboratory situation. Second, the type-S independent variables employed, age and sex, enjoy a high degree of precision in their manipulation. Very little error is involved in manipulating age (for example, an animal claimed to be 90 days old might actually be 89 to 91 days old), and none at all in manipulating sex (it is virtually impossible for an experienced E to mis-sex an adult rat). The guiding principle, then, is that research utilizing only type-S independent variables may nevertheless be classified as experimentation when it takes place within a well-controlled laboratory setting and when the type-S independent variables allow for very little error of manipulation.

64 We may summarize the preceding criteria of classification as follows:

1. Observation is research that involves no independent variables; it is called either natural observation or laboratory observation depending on whether the observation takes place in a natural or laboratory setting.
2. All research involving at least one type-E independent variable is classified as experimentation and constitutes the bulk and body of experimental research.
3. All research employing only type-S independent variables in a natural setting is considered correlational research.
4. All research making use of only variables that with equal appropriateness qualify both as independent and dependent variables is also classified as correlational research.
5. Research employing only type-S variables in a laboratory setting may be classified as experimentation or correlational research depending on the rigorousness of the laboratory situation and the degree of error involved in the manipulation of the independent variables.

65 It is not difficult to generalize and apply the preceding concepts to research in sciences other than psychology. We need only adjust our interpretation of that portion of the definition of dependent variables that reads: a dependent variable is . . . any behavioral variable measured by E. Behavioral variable would simply be interpreted as any variable relating to the appropriate behavioral aspects of the objects or things with which the science deals. Psychology, then, is the special case in which the “objects” are living, usually higher, organisms and the “appropriate behavioral aspects” encompass such processes as sensing, per-

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1. It is interesting to observe that the independent variable rearing condition could also be manipulated by selection. Imagine that our animals’ caretaker, in assigning newly weaned infant rats to cages, performed his task somewhat indifferently, housing some animals alone and others in pairs. Suppose that, wishing to investigate the rearing variable, we took advantage of the caretaker’s small dereliction and chose (selected) as Ss for our study a group of animals reared alone and a group raised in pairs. Clearly, we would then be dealing with a type-S independent variable, because manipulation is not direct but rather occurs through a selection procedure. With respect to the three differences between type-E and type-S independent variables discussed earlier, the major advantage of direct manipulation over selection is, in the present instance, that it is easier to avoid concomitant manipulation of potentially relevant variables. For example, suppose that unknown to us the caretaker had developed the habit of housing aggressive animals alone, pairing off the more timid rats. Consequently, in manipulating rearing condition, we would also unwittingly be manipulating aggressiveness or “fearfulness.”
ceiving, and learning. Within this generalization, research in astronomy is largely, if not solely, correlational because its independent variables cannot at present be manipulated directly and the events which it studies are as yet incapable of being controlled or constrained in any way by E; that is, its research occurs in a natural setting. Physics and chemistry, however, are among those sciences whose accomplishments in recent times form the foundation of the widespread faith in the power and efficacy of experimentation.

Classification Of Variables

66 It will be recalled that a variable was very generally defined as any measurable attribute of objects, things, beings. Despite the requirement of measurability, the inclusion of such qualitative variables as sex, race, and religion was specifically noted. The purpose of this section is to clarify the distinction between qualitative and quantitative variables and to consider the subdivision of the latter into continuous and discrete variables.

Qualitative and Quantitative Variables

67 In psychology, qualitative variables often relate to aspects or properties of the organisms under study, for example, species and strain membership in animals and race, religion, occupation, and personality classification in humans. Qualitative variables are, however, also encountered elsewhere. A qualitative stimulus variable was employed in the reaction-time experiment described earlier, namely, type of stimulus presented S, tone or light. The essential feature of qualitative variables is that they are composed of categories which do not bear a quantitative relationship (one of magnitude) to each other [italics added]. Or, what is essentially the same thing, the categories of a qualitative variable do not lie on a dimension that lets us make such statements as “Category A possesses a greater magnitude of the variable than category B.” Thus, for example, a researcher studying how emotionality and strain membership are related in rats has strain membership (for example, Wistar strain versus Sprague-Dawley) as his independent variable, the separate categories of which cannot be placed into an order based on magnitude. It is meaningless to assert that the Wistars have more “strain membership” than the Sprague-Dawleys, or that Catholics have greater “religious denomination” than Mohammedans. We therefore define qualitative variables as those variables composed of categories which cannot be ordered with respect to magnitude.

68 Quantitative variables, on the other hand, always refer to attributes of objects or things which embody magnitude as an essential characteristic; therefore, questions relating to “how much” make sense with these variables [italics added]. Thus age, intelligence, number of trials to learn an experimental task, and intensity of an auditory stimulus are all quantitative variables because individuals may vary in magnitude of age, intelligence, and number of trials to learn a specific task, and an auditory stimulus can differ in the magnitude of its intensity. In summary, any variable that can be ordered with respect to magnitude is a quantitative variable.

69 Needless to say, quantitative variables are preferred in scientific work for the simple reason that they lend themselves to much more precise and fruitful measurement than qualitative variables. There is, in addition, little explanatory power in qualitative variables. When a qualitative independent variable influences a quantitative dependent variable, one quite naturally seeks to attribute the effect on the latter to a quantitative variable that is somehow associated with the manipulated qualitative variable. To illustrate, it is well established that reaction time to sound is usually faster than reaction time to light. One possible interpretation of this result is that sound stimuli activate their receptors in the cochlea faster than light stimuli excite their corresponding receptors in the retina (rods and cones) because relatively slow photochemical processes are involved in the latter (Woodworth & Schlosberg, 1954, p. 18). Thus, differences in RT
brought about by manipulation of a qualitative independent variable, type of stimulus, are explained by referring to differences in an associated quantitative variable, time to excite the respective receptors.

**Continuous and Discrete Variables**

70 Quantitative variables are separable into continuous and discrete variables, the majority of quantitative variables in psychology falling in the former category. A continuous variable may be defined as a quantitative variable which can be measured (i.e., ordered with respect to magnitude) with an arbitrary degree of fineness, usually depending only on the precision of the available measuring instrument. Reaction time is plainly a continuous variable; it can be measured with any degree of fineness or exactness that one chooses, subject only to the limitations of the currently available measuring tools. At one time, because of the limitations of the then existing instruments, RT could be measured at best in milliseconds; today, if required, it could be measured in microseconds, a thousandfold reduction in the size of the measuring unit.

71 Consider, however, number of siblings as a variable. This is a discrete variable because no amount of refinement of measuring instruments or techniques can produce a value of, say, 2.5 children. Similarly, the number of digits that can be immediately recalled, as well as the number of heads obtained in 10 tosses of a coin, are also discrete variables. As a general rule, in psychology discrete variables are variables whose values are obtained by counting, so that the specification of the variable normally begins with "the number of." One must be careful, though, to distinguish between the basic nature of the quantitative variable in question and the means by which it is measured. For example, level of achievement in a college algebra course can be measured by the number of items correctly answered on a final examination. Clearly, the underlying variable, level of achievement in the course, is a continuous variable, even though it is measured by the number of items correctly answered on a final examination. In fact, the physical measurement of all continuous variables can be interpreted to involve counting. Age, height, and weight, all of which are continuous variables, are often measured in terms of the number of months of age, the number of inches in height, and the number of pounds of weight. But unlike true discrete variables, the measurement of these variables can be refined almost endlessly so that, if one wished, their measurement could be in terms of the number of days of age, the number of hundredths of an inch in height, and the number of grams of weight.

72 In summary, all variables in psychology may be classified as either qualitative or quantitative. Qualitative variables are composed of categories that cannot be ordered with respect to magnitude. Quantitative variables, in contrast, do lend themselves to ordering with respect to magnitude. Quantitative variables may be classified into those that can be measured with an arbitrary degree of fineness and those that cannot. The former quantitative variables are called continuous variables; the latter, discrete variables. It follows that type-B independent variables may be qualitative, continuous, or discrete variables, and the same holds true for type-S independent variables. Dependent variables are sometimes qualitative, as often found in studies involving personality projective tests, though most often they are quantitative, in particular, continuous, variables.

**Operational Definition of Variables**

73 The purpose of this section is to point out that descriptions of variables, independent and dependent, can vary widely in their degree of generality. To illustrate, suppose E, employing a separate-groups design, performs an experiment in which hungry rats run down an alleyway at the end of which they find food in a goal box. One group of rats always finds a single food pellet in the goal box, a second group finds two pellets on all trials, and a third group, four pellets. The experimenter is interested in how speed of running is affected by the number of food pellets that S finds in the goal box.
The independent variable of this study may be described in several different ways. “Number of food pellets” is a reasonable description, but “amount of food reward” and even “amount of reward” are also possibilities. Note that these descriptions differ in their generality. When \( E \) varies number of food pellets, he is of course varying amount of food reward; but, and this is the important point, he could have manipulated amount of food reward by means other than varying the number of food pellets, for example, by varying the concentration of a sucrose solution. Amount of reward is a still more general description of the independent variable, including, as it does, manipulations of amount of food reward, water reward, and any other commodity which could serve as a reward for rats.

To distinguish descriptions which are couched in terms of the actual operations performed by \( E \) from other, more general, descriptions, we refer to the former as “operationally defined,” or more briefly, “operational” independent variables. Thus number of food pellets is the operational independent variable in the previous illustration. Of course one can argue that even this definition contains a residue of generality, because food pellets can differ in composition, size, etc. Although a more precise operational definition would specify the latter properties of the food pellets, experience is often a reasonable guide as to which properties can be safely ignored.

In most cases \( E \)'s interest lies less in operationally defined independent (and dependent) variables than in generalizations thereof. In the previous example, \( E \)'s concern might be how amount of reward influences behavior in the runway. Although much psychological research is stimulated by hunches or hypotheses about relationships between independent and dependent variables defined in general terms, to submit such hypotheses to empirical tests one must resort to operationally defined variables. Ordinarily the transition from a generally defined variable to its operationally defined counterpart presents little difficulty. What does present a major problem is showing that different operationally defined realizactions of the same variable in a reasonably consistent way. To cite one illustration, there are several ways of operationally defining hunger drive: for example, hours of food deprivation, maintaining a certain percentage of free-feeding body weight, and the use of drugs. The effects of these various methods of manipulating hunger drive on behavior differ, however, by no means equivalent.

It is not our purpose here to pursue this very critical problem. It is sufficient to realize that different levels of description of independent and dependent variables exist and to note the level of generality of the independent and dependent variables encountered.

Summary

The summary of this chapter and later chapters is left to the student, although a guiding outline is provided, it is important that the student complete the summary, not only because it serves as an informal test of his grasp of the chapter’s content, but also because the summaries will later provide a convenient means of review.

1. Psychological research may be subdivided into two interrelated categories:
2. The first category consists of two major activities:
3. Within the second category three major research approaches may be distinguished:
4. (a) A variable is defined as:
   (b) To manipulate a variable means:
5. A relevant variable is defined as:
6. An independent variable is defined as:
7. (a) A type-E independent variable is:
(b) A type-S independent variable is:

8. Three advantages that type-E independent variables often have over type-S independent variables are:

9. (a) Single-group designs differ from separate-groups designs as follows:
   (b) The illustrative reaction-time experiment is an example of:

10. A dependent variable is defined as:

11. When research is classified in terms of the nature of the independent variables employed and the research location, five criteria result by means of which we may assign a given piece of research to one of the three major research approaches. These five criteria are:

12. All variables are either qualitative or quantitative.
   (a) Qualitative variables are defined as:
   (b) Quantitative variables are defined as:

13. Quantitative variables may be either discrete or continuous.
   (a) The definition of discrete variables is:
   (b) The definition of continuous variables is:

14. Operationally defined independent and dependent variables are: