# **CHAPTER 3**

# Knowledge

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# **CHAPTER 3**

# Knowledge

After discussing our professional goals (i.e. that we want to be ethical and prosperous) and thereby the criteria by which we should select the way we go about conducting psychology, we determined that a clear "understanding" of the "truth" would provide us with what we wanted. We also came to realize that those were the very products (output) of science. Next we considered the process, or activity, of science by reviewing a variety of ways to define science.

In this chapter we will address: to what does science ask its questions and what is the nature of the response to those questions. We will see that we are interested in the relationships between observations, and that that information is the foundation for our ability to predict, control, synthesize, describe, and explain nature. We can get that information (i.e., "knowledge") directly through research or indirectly through vicarious experience such as reading a journal article or solving a math problem. Obviously some scientists generate knowledge, while others use that knowledge, while others take that knowledge as the question to begin with.

Often common conceptualizations of knowledge imply that it is something within an individual without much effort given to understanding how that stuff called knowledge gets inside the individual and how different environmental interactions result in different internal knowledge. This text takes a functional approach. Knowledge is seen as exposure to relationships in nature that result in different behaviors. Whether knowledge is also something contained in the mind within the individual is seen as an irrelevant question. This chapter addresses itself to reliable covariance between nature and behavior and the issues pertaining to it such as how to think about that covariance and what subset to select. Again the label, "knowledge," is inessential while the details of the referent are critical.

# I. Conceptual Precursor: Knowledge of What? What is Knowledge?

#### A. The Nature of Knowledge

What is it to truthfully understand nature? We want to correctly describe, predict, control, synthesize, and explain nature. In order to predict nature, we

must know something which will reliably warn us, or give us notice of an upcoming change in our variable of interest. In order to control nature we must know those variables which reliably modulate, or which are necessary or sufficient to change our variable of interest. We can synthesize something only when we understand how precursors can be combined to produce some new change or event. Similarly, we can explain nature only when we can specify the general class of functional relationships which are the general case of the specific changes we observe and understand how those particular changes fit within a larger and more integrated paradigm.

#### B. The Provenance of Knowledge

We address ourselves to nature. The natural world is all those things which affect us and the things around us. It is the things that are observable and are therefore labeled as real.

Because we want to know how to correctly understand our environment, we look to the natural world for our answers because that foundation has been shown to be the most successful.

#### C. The Vehicle of Knowledge

We react to changes in nature. If we see this page it is because the light changes as we move our eyes from the desk to the book. There are many types of change and many issues to consider when thinking about change.

# II. Conceptual Precursor: Change and Equilibrium

#### A. Change

If the value of the dependent variable changes from one individual to another, or if a single subject reacts one way on one occasion and a different way on a different occasion, how are we to conceptualize that change? How are we to extract order from change?

#### 1. Conceptual Precursor: Determinants of Variability a. The Assumption of Intrinsic Variability (no cause)

From this perspective, variability has no cause; it just happens and it, in principle, cannot be predicated.

i. Outside Organism



ii. Inside Organism



Clearly, this approach would lead to little gain in the understanding of nature.

#### b. The Assumption of Strict Determinism (due to cause)

From this perspective all variability has a cause. A strict deterministic philosophy is consistent with stochastic behavior which has no apparent determinant, in that there are systems where even very small disturbances can result in very large changes in the dependent variable (butterfly effect).



The assumption of intrinsic randomness and deferral of explanation are seen as last resorts. In many cases, as a matter of practicality, we will have to accept that the deterministic source of the variation is beyond our resolving power. We get things handed to us like the distribution of electrons in any single atomic shell. The dilemma is that if we accept randomness at the broadest level, science ceases -- everything is simply random. If two children score differently on a test, nothing could be understood or done about it. On the other hand, if we require absolutely no variance in our measures, science will also cease because we would never get a clear answer to an experiment.

#### 2. Conceptual Precursor: Size of Measurement Window

Measures of behavior are in the form of some number of events or magnitude over some amount of time. So in some sense measures are always averages, the only useful averaging window is one that is neither too large nor too small. If the window is too small, successive exposures will be either one or zero, and the real time behavior is simply translated into a string of ones against a background of zeros. We have only raw data. If the window is too large, we have either no change in the behavior because all instances of the behavior are in the same bin or we have only a few data points across the *x*-axis. The problem with too few data points can be illustrated with the well known FI scallop. In a single bin case, the systematically changing rate across an entire fixed-interval schedule would collapse to a single rate thus abolishing an important dependent variable of interest, i.e., the nature of the behavior change across the fixed interval.

#### a. Averaging Window Appropriate

The fine structure of interest is revealed.

#### b. Averaging Window Too Small

If the averaging window is too small, the results will closely approximate raw data.

#### c. Averaging Window Too Large

If the averaging window is too big, the dynamics are conflated into a single number.

#### 3. Three Types of Behavior Change a. Transient Dynamics

Transient dynamics are the temporary real time variation in behavior associated with some change in the schedule such as the change in behavior with the first exposure to some new but continuing task (e.g., the learning curve).

If a rubber ball is dropped onto a floor, it bounces in ever decreasing bounds until it comes to rest on the floor. The same thing happens with a pendulum, swinging in decreasing arcs until it comes to rest, a bouncing ball and a pendulum are illustrations of damped systems. Transient dynamics are the one-time change which occurs with a change in conditions until the ball, pendulum or behavior comes to "rest" or asymptote.



Acquisition (or extinction) of a behavioral equilibrium follows the same negatively accelerated path as the height of the bounced ball.



The following figures illustrate transient change as behavior reacts to events. Examples are acquisition of behavior to a new task, the loss of behavior under extinction, and the change in behavior following some disturbance.



In each case the behavior change is with respect to some nonrecurring explicit change in the environment.

#### b. Synchronous Dynamics

Synchronous dynamics are the real-time commonalities in the change in behavior associated with repetitive predictable changes in a schedule. In the case of an evoked potential to a light flash, a signal averager averages brain activity in synchronized consecutive bins following each flash.

If an animal is exposed to a schedule which has a regular predictable change in the contingency such as a fixed-interval schedule, the behavior shows a systematic change in rate as a function of the passage of time since the start of that interval.



The above figure illustrates synchronous dynamics in a fixed-interval (FI) schedule. In an FI, the mean behavior is called an FI "scallop." Behavior can be averaged across repeated instances of each specific ordinal bin if the successive bins are synchronized to the event which controls behavior. In this case, the passage of time since the beginning of the interval. The first bin of the first trial is averaged with the first bin of the second trial and of the third trial etc. The second bin of the first trial is averaged with the second bins of the second trial and the third trial and so on. In this case, data from trial 1 or trial n can be freely interchanged, but the position within each trial with respect to the synchronization point is not free to vary.

The synchronous average can be a correct portrayal of the typical moment-tomoment change across the bins of the sampling domain as the above figure suggests, or the average shape of the individual functions may not represent any of the individual functions and the average function can therefore be an artifact.



For example, if each different fixed-interval schedule produced a break-andrun pattern of responding, but each run started at a different point in the interval, then the synchronous average would incorrectly indicate a smooth scallop.

#### c. Asynchronous Dynamics

The final class of real-time behavioral variability is asynchronous dynamics. Asynchronous dynamics is the variability seen even after very extended exposure to the same treatment. An undamped system continues to oscillate forever rather than to eventually cease. Brownian motion, background radiation, a clock with an electric motor, or a ball on a moving ping-pong paddle continue to oscillate until the energy is removed.

The behavior of living things also exhibits chronic variability. This is problematic in that it is not associated with a change in conditions, is not temporary, and has no apparent "cause." It is the variability seen after the transient dynamics have passed and in the absence of any known disturbances. These dynamics can be quite large even under extremely regular conditions which have been in effect for very long times. The figure below illustrates asynchronous dynamics before and after a schedule change (which have resulted in a transient dynamic).



In research on asynchronous dynamics, the ordinal position of each instance is important and no item can be interchanged with any other item. The right portion of the figure illustrates the typical approach taken to asynchronous dynamics. As will be discussed below, asynchronous dynamics is generally ignored and the mean and standard deviation of the variability is specified following exposure sufficient to eliminate any consistent trends.

#### B. Equilibrium

At equilibrium the tendency to increase or to decrease are in balance. A mechanical metaphor for equilibrium is a weight on the end of a spring:



The spring pulls up and the weight pulls down. They come into equilibrium. When the vertical position of the weight stabilizes at some point, the forces pulling in each direction are in balance. Adding or removing a weight in this weight-and-spring example is a metaphor for the change in equilibrium caused by the change in reinforcement contingency.

#### 1. The Characteristics of Equilibrium States

Dependent variables change and establish new equilibria as a function of changes in other variables. How the measures change and reequilibriate are frequently characterized with the following terms:

#### a. Neutral Equilibrium

The measure is stable in its initial state. All changes are equally easy to effect and after the change, the variable exhibits stability at that new value. This is the prototypical type of equilibrium. Typical examples would be the weight and spring one already given or the position of a ball on a plane, movement to any other position is equally difficult and the new position is static until a change in variables changes it to some other position.

#### b. Stable Equilibrium

The measure is stable in its initial state. The effect of any given variable has a tendency to have only a temporary effect and the original condition tends to be recovered. For example, forces that tend to move a ball at the bottom of a bowl tend to move it up the side, but the ball tends to roll back to the bottom of the bowl. An alternate example is a pendulum at its center bottom.

#### c. Unstable Equilibrium

The measure is stable in its initial state, but any relatively small influence tends to be able to change the state of the system to a very different state that is also stable. For example, a ball on a ridge, or a pendulum balanced at the top of its axis. In both cases, a very slight tap will result in a change and the new state is more stable than the prior unstable state.

#### d. Metastable Equilibrium

The measure is stable in its initial state. Moderate variables have a reversible effect just as would typify a stable equilibrium but a relatively strong variable is capable of changing the state to a new but very stable state such as characterizes unstable equilibrium. For example, a ball pushed completely off of a flat table top onto the floor.

#### C. Change, Equilibrium, and Research Focus

Most typically, the behavior change obtained from an experimental procedure is expected to be a damped function (i.e., transient dynamics). As the process reaches equilibrium, its oscillations are expected to diminish to zero. To the extent that the undamped variability is small with respect to the treatment effect, it can be ignored as a simple matter of triage and the primary research question can be considered answered. If the undamped oscillations are large with respect to the experimental treatment effects, then the experiment provides little gain in knowledge concerning the effect of the treatment variables.

An alternate perspective would focus on the asynchronous variability itself. In this case, the research is aimed toward characterizing the dynamics of behavior. The issue is one of characterizing the nature of the variability and subsequently predicting, controlling, and synthesizing it. In the case of asynchronous dynamics, the question becomes what does variance in responding mean as opposed to measures of central tendency? If a manipulation changes the amount of variance but not the mean rate what was done? Is it always the case that that manipulation was only releasing different amounts of control and is therefore a random effect. If it were a random effect, what does it mean to say such a thing?

# III. Knowledge is Covariance

As was discussed, things in nature change. The lights in a room may be on or off, a rat may be in the right or the left arm of a maze, a silent person may begin to speak. We flip the light switch, we place food in one goal box, we ask a person a question. Often, however, things are not so dichotomous: Dawn changes darkness to light in a continuous fashion. The number of soft drinks consumed per day varies, and people speak in a variety of rates, amplitudes, and languages and say a variety of things. There are both continuous changes and dichotomous changes in nature.

We also see relationships in nature; we flip the light switch and the lights go on, we place food in one goal box and the rat goes there, we ask a person a question and they answer. Additionally, we may not see simple discrete causeeffect relationships, but rather covariance. As consumption of cigarettes increases, incidence of cancer increases, but everyone smoking does not get cancer, and many people get cancer who have never smoked. Some relationships are very strong like light switches and illumination level (often labeled "cause") while others are weaker like social status and success in college (often labeled simply "covariance" as opposed to cause).

#### A. Simple Dichotomous Change and a Necessary and Sufficient Precursor

A very simple mechanical example of a dichotomous change caused by a necessary and sufficient precursor is a light switch position (up or down) and the amount of light in a room (bright or dark). The figure below illustrates a dichotomous change in the number of birds in North and South America between the dichotomous periods of winter and summer. Each dot could represent some millions of birds. In winter, all birds are in the south (in terms of the weight/spring metaphor, the suspended weight is in lower position). In summer, all birds fly north (some weight is removed and the suspended weight rises). When winter returns, all birds fly south (more weight is added again and the suspended weight returns to the lower position).



The effect of reinforcement on behavior provides a psychological example. If you follow a particular behavior such as key pecking (the dependent variable) with food (a reinforcement contingency; the independent variable), the changes could be represented as follows:



The figure shows an initial zero frequency of response-dependent food presentation (the heavy line) with an initial zero or near zero rate of key pecking (the thin line). This relationship is stable and we can label it an initial baseline (a spring with weight on it). The environment is then changed, food presentation now follows key pecking (the existence of a reinforcement contingency changes from zero to one) (some weight is removed from the spring). This is followed by a gradual increase in the rate of key pecking (the position of the suspended object rises). This is typically labeled the "learning curve." Eventually stability recurs. The response rate is then said to be at asymptote (i.e., it no longer changes). The two variables are again in equilibrium.

The reinforcement contingency for key pecking can subsequently be returned to its initial state (food no longer follows key pecks) (the extra weight could be replaced), and the response rate returns to its baseline level (the position of the suspended object falls). This rate loss is typically labeled the "extinction curve". Eventually equilibrium is reestablished.

#### B. Continuous Changes and Continuous Relationships

Changes are often more complex than the simple dichotomous changes with dichotomous causal factors, just illustrated. The complex case can be easily illustrated by continuing the example of the migration of birds. Changes can be continuous like dawn rather than dichotomous like a room light. Changes can be statistical like the percentage of birds in each location. Not all need fly south. 100% can be in Canada and 0% in South America or the reverse or anything in between. In fact, the birds may stop in the US, Panama, or anywhere in between or some could even migrate backwards.

This next figure illustrates most, but not all, elements in the dependent variable (dots or birds) "switching" with a change in the dichotomous independent variable (season).



Further, it can be seen that change can be continuous in both its x and y amount. This is illustrated by plotting the data as a function of both all twelve months (A through G) and all ten latitudes (I through X) which gives us a more typical and more useful example.



This last format provides for:

## 1. Continuous Predictor (X)

Time A through G x x x

## 2. Continuous Predicted (Y)

(location of birds) I through X

- X
- Х
- x

## 3. Continuous Relationship Between X and Y

Illustrated in the following figure

x x

Not only do we get continuous x and y, but we can also get weak or strong relationships and positive or negative relationships.

The following variations are illustrated with scatter plots



and scatter plots with added regression lines, which dramatize the general trend.



## C. Multivariate Change

Clearly a single dependent variable can change as the result of more than one independent variable. In fact, the dependent variable may not change unless several independent variables are manipulated in a particular way. Additionally, a single independent variable may cause several dependent variables to change. In this light, the previous examples can be seen as special cases of what changes we could expect in the natural world. The earlier examples have only one independent variable and one dependent variable; they are called univariate. The multivariate nature of the natural world is often overlooked because there has been such a long tradition of considering only univariate relationships because the analytical tools for multivariate analysis have only recently become available.



In the above figure, it can be seen that 2-year old birds fly south for the winter, 4-year old birds stay around the equator all year, while 6-year old birds migrate north for the winter.

- 1. Number of Independent Variables
  - a. One IV
  - b. Many IVs
- 2. Number of Dependent Variables a. One DV
  - b. Many DVs

#### D. The Analysis of Variability

The first step in analyzing variability is to consider what is causing the variability. The solution is that the individual researcher is obliged to attack the major sources of variance in the phenomena of interest first, and report stability and accountable variance of the same magnitude as other researchers in the field. In a sense, status in science goes to the researchers who have the least variability in their data. Any difference between subjects (or between different instances with the same subject) is presumed to be the result of deterministic differences between those subjects or those situations. Research explains the variability by demonstrating covariance with the "cause" and no covariance without the cause. An initial step in the answer to the question of why the birds are sometimes in Argentina and sometimes in Canada is discovering the way the scores could be grouped (e.g., treatment, no treatment; or group 1 versus group 2) such that accountable variance is maximized. In the migrating birds example, it would be what we have already done, group the dependent variable by season or

by month. Most of the variability would then be accounted for by the time of year. In this case, the cause is the specification of the month. The differences in the subjects can be conceptualized as occurring at a variety of levels (e.g., chemical, biological, psychological) or as the result of experiences across a variety of time scales (e.g., evolution, developmental, learning). These frameworks will be developed in detail in Chapter 7. Variance is said to be accounted for when we know why and how much the scores vary. It is said to be residual when we don't understand why.

#### 1. Accountable Variance or Covariance

Suppose we go around a typical class and ask each person for their GPA and shoe size and we plot the left scatter plot below. We go up the y-axis their GPA, then across the x-axis their shoe size. We place a dot in that spot to represent that a person with that GPA and that shoe size occurred. We would notice that there are more people of average GPA than very high or very low. There are more dots in the middle y values, than at the extreme y values. This can be seen by imagining that each dot is a ball bearing and we tilt the page to the left. If the bearings roll straight to the left they would form stacks against the y-axis as is illustrated. There would be many in the middle, few to the top or bottom. Similarly, there are more values at middle x values. We can tip the figure and roll the dots into piles on the x-axis. Many would be in the middle and few to the left or right.

Next we repeat the whole plotting process by asking each person for their grade point average and hours studying and form the right figure below. Again there are more middle GPA people than low or high. There are also more middle studying people than little or lot.



Note that the variability around the average Y (GPA) is the same in both

figures (as it should be because it is the same measure), and the variability around the average X is the same in both figures. However, in the right figure we could find a way of looking at the figure (in this case up the line drawn at an angle through the origin) (plotting the information in other than z-scores would have other slopes and intercepts) which dramatically reduces the error or variance around a central tendency. This is illustrated by the distribution drawn in the lower left corner of the right figure. If we had tilted the right figure at a 45 degree angle than the stacks of ball bearings would have been very close together and would have created the distribution in the lower left corner. This error is very much smaller than that on the x- or y-axis.

The figure on the left has the same spread around the x- and y-axes, as the right figure but it does not have any "line" around which the spread is minimized more than it is by the mean. A line from the origin similar to the one in the right figure is drawn for reference, but clearly the spread around it is not better than around the mean y. Prediction is relatively good in the right figure and poor in the left figure. If you start on the x-axis with a shoe size (left figure) or hours studying (right figure) that you know, you can then look to see what y values have occurred for your given x value, you can predict what GPA will occur based on that information. If we know a person's shoe size, we cannot accurately predict their GPA very well (left figure), whereas if we know their hours studying, we could predict their GPA with reasonable certainty (right frame). As can be seen on the left, reasonable predictions are not possible with a zero relationship, no information is available at all. Whereas with the strong relationship on the right, accurate predictions can be made.

Those two relationships can be illustrated yet another way. Each circle below represents the variability in a set of numbers. The area of the circle labeled Y represents the variability on the *y*-axis. The area of the circle labeled X represents the variability on the *x*-axis. The intersection of the two circles represents the covariance while the area in Y remaining in addition to the overlap represents the residual variability around the best fit line through the data points or the variability in Y not "explained" or accounted for by the variability in X. The unexplained variance is the variability in the distribution at the lower left corner at the end of the diagonal line of the previous figures. The explained or "accounted for" variance is the difference between the distribution on the *y*-axis and that around the best distribution in the lower left corner.



As we will see in subsequent sections, meaningful information requires four elements: variation on the "X" dimension; variation on the "Y" dimension; reduced variability around the regression line as compared to around the mean; and sufficient spread in the elements or data points on each axis.

#### a. Models of Accountable Variance

There are several types of models for accountable variance. They differ with respect to what is known, or what information is specified by the model, and the degree of control over the environment offered by that information.

#### i. Cause Effect Models

The two types of cause-effect models are provided below. Note that it is necessary to experimentally manipulate the relevant variables to prove that a cause-effect relationship exists.

#### (a) Mechanistic or Reductionistic Models

Some things, like a billiard ball moving as the result of being hit by the cue ball can be seen in a cause-effect framework where each step in the process is well understood. A light switch and room illumination is another example. (Manipulation --> change; known reductionistic mechanism of action.) What molecular steps or processes led to the end are known, at least at one level down from the level of the dependent measure.

#### (b) Functional Models

Things often stabilize in predictable ways without us understanding (or caring about) the reductionistic processes or all the intervening steps involved. For example, the rate of responding changes in orderly ways when the reinforcement rate changes. It helps little to explain behavior by saying that an unspecifiable reductionistic force causes it or the rate changed because the animal knew something. What Newton said of celestial mechanics is applicable to behavior: "I have not been able to discover the (reductionistic) cause and I make no hypotheses."

In functional models, explanation is the specification of necessary and sufficient conditions at the same level of measurement as the dependent variable. Note that a functional or correlative model is typically causal, while a correlational model is not causal. (Manipulation —> changes; unknown reductionistic mechanism of action, but known order of effect and set of necessary and sufficient conditions).

#### ii. Correlational Models

Sometimes we only know that things go together. One thing is not known to cause the other. Additionally, we may not even know which of the two events comes first. Social respectability and wealth covary. One can be predicted from the other but one does not force the other. Any of three relationships could underlie the prediction. It could be  $A \longrightarrow B$ ;  $B \longrightarrow A$ ; or  $C \longrightarrow A$  and B. (No manipulation; predictor  $\longrightarrow$  predicted with unknown order of effect.) (Subsequent experimental research could find the order of the effect.) It is important to realize that knowing only that two things covary is a substantial and important piece of information. Note that a correlational model should not be confused with a functional or correlative model or explanation.

#### 2. Residual Variance, Error, or Ignorance

When we have discovered why something happens, we have removed the accountable variance (the overlap in the Venn diagrams). The next question is obviously what to do with the variability which we do not understand.

#### a. Experimental Solution

The obvious and productive solution to the problem of residual variability in the data from the subjects is to do an experiment which answers "why." Why do these individuals score higher, how can I predict which of the scores will be higher? What will change an individual? By manipulating variables, you can find the answer.

#### b. Assumption of Nonlinear Dynamics

There are ways for a few simple completely deterministic variables to interact such that the result is a seemingly random series of measures ("chaos theory"). The resulting variations cannot always be proven nonrandom by simply observing the output. By developing a model of the processes underlying the behavior those factors could be resolved. It should be noted however that without the "de-encryption key," this interpretation is purely metaphysical. Without some coherent and broadly-based theoretical framework and substantial empirical support for a particular nonlinear dynamical causal factor, "chaos" is not an explanation, it is only a possibility

#### c. Assumption of True Score and Random Error

While not properly a solution, this approach allows the researcher to "pass" on the problem. A property of randomness is that deviations occur to either side of a true score to the same extent. The mean of random errors therefore cancel. If we presume that our obtained scores are randomly distributed around a true score then the mean will be the true score. If we have unaccounted for variability in our data, we can presume that it is random and of no interest by taking the average of our scores. However, we are: 1) presuming something (randomness) which we do not know to be true, 2) ignoring something which may be of importance, 3) giving up opportunities to explain variability, 4) assuming that each element in the group over which we are taking the mean is identical, and 5) that the relationship between the elements is linear. Undoubtedly some variability should be passed over. It is equally true however, that some variability is of great consequence.

#### d. Delegation of the Problem

What appears to be a simple solution to residual variability is the "tag team solution." When faced with a problem which, for that individual, is insurmountable, they could do like the wrestler does: Rush over to the ropes (the boundary of their domain) and give the problem to someone else. This would be contending that there is a biological explanation for your psychological data or a developmental explanation for your obtained difference in learning. These deferrals are different from experimental solutions because the investigator who invokes them does not pursue the problem across the boundary, but rather lays a problem at someone else's doorstep and then acts as if the problem is understood by using the invoked paradigm as an explanation rather than a description of ignorance. Passing an unsolved problem to some other domain is a mark of inadequacy, not a badge of honor. Chapter 3 - CF