3.4 Model Selection and Testing: Concluding Remarks

Theoretical results obtained in the context of nested families of distributions show that *BIC* identifies the correct model with probability converging to one, as the sample size increases, whereas a similar asymptotic consistency is not given for *AIC*(Jungeilges 1992). However, most distributions underlying real data are likely to be much more complex than the most complex model considered for selection. Under this premise, all of the above selection methods favour the most complex models among the considered models as sample size increases, because estimation variance, but not model bias, converges to zero as *n* goes to infinity. That is, in large samples, selection is dominated by the degree of misspecification of given models so that non-parsimonious models with more ability to approximate the underlying complex distribution are selected. Similarly, in this situation, any model is eventually rejected in model testing as the test power of model tests for detecting even tiny model violations increases with increasing sample size.

Another class of problems is subsumed under the label model selection bias (Chatfield 1995). Model selection criteria are themselves random variables and thus subject to random error. As a consequence, which model is selected for further inference or prediction is uncertain, and there may be a substantial probability that another model is chosen if the model selection procedure is repeated on the basis of a new random sample. Note that this is a fundamental problem that also applies to criteria based on cross validation.

This has several consequences. The criterion value of the selected model will in general appear too good, because overfitting may have contributed to the model's eventual selection success, and nominal standard errors of parameter estimates and nominal levels of significance tests based on the selected model will be incorrect because they do not take model uncertainty into account. Several approaches are being discussed for dealing with this issue. In Bayesian model selection, model uncertainty can be incorporated explicitly by model averaging (see above). Furthermore, through appropriate bootstrap and cross-validation techniques, model selection can be built explicitly into statistical procedures (Hjorth 1994). Further relevant references are Buckland et al. (1997) and Ye (1998).

See also: Goodness of Fit: Overview; Goodness-of-fit Tests and Diagnostics

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K. C. Klauer

Models: Philosophical Aspects

Contemporary philosophers of science argue that models are a major vehicle of scientific knowledge. This applies to highly theoretical inquiry as well as to experimental or otherwise observational research, in both the natural and the social sciences. Making this claim is not yet very illuminating, given that there is a large variety of different kinds of model, and a number of ways in which they function in the service of science.

The ambiguity of the term 'model' and the multiplicity of kinds of model are illustrated by Pierre Duhem's famous comparison of the mind of a continental physicist to that of an Englishman: the former strives for 'theories' that are formulated in 'the clear and precise language of geometry and algebra' and consist of abstract and idealized notions and formulae, while the latter insists on having mechanical 'models' that satisfy 'his need to imagine concrete, material, visible, and tangible things' that are familiar to ordinary experience. While the French or German physicist deals with a formalized theory in his account of electrostasis, the English account is in terms of 'strings which move around pulleys, which roll around drums, which go through pearl beads, which carry weights; and tubes which pump water while others swell and contract; toothed wheels which are geared to one another and engage hooks. We thought we were entering the tranquil and neatly ordered abode of reason, but we find ourselves in a factory' (Duhem 1954, pp. 70–1). Models in this sense—iconic models —employ analogies to visualize the mechanisms depicted, while formalized theories supposedly lack this property. On the other hand, it is nowadays customary to use the term 'model' also for such formal systems of equations, conspicuously so in the social sciences—and, much of the time, such formal systems are used for representing causal mechanisms. In relation to such a formal system, 'model' is also used for its various interpretations, or just for the interpretation that makes it true. The model muddle needs to be sorted out.

1. Typologies and Distinctions

In ordinary language, the term 'model' is used to stand for many things, such as a type of design (the fashion industry's new spring models; the 1997 model Saab; the German model of industrial relations) and an exemplar: an object proposed or adopted for imitation (a woman displaying clothes in fashion shows; a model wife; a person posing for artists and art students). The term is also used for what are often called scale models or replicas, such as an architect's design of a house presented as a miniature construction (here the thing modeled does not yet exist—the model is used in the process of producing the thing); and three-dimensional depictions of the atom and the solar system exhibited in science museums (here the thing modeled already exists).

In meta-logic, a model of a theory is any set of entities or a structure that satisfies the axioms of the theory. Here 'theory' denotes a formal, uninterpreted system of axioms and deductively implied theorems. In the traditional usage of 'model' in the social sciences, this idea becomes reversed: it is such formalized or semi-formalized systems that are often called by the name 'model'—in contrast to verbal theories.

There are attempts to classify types of model, but none of them is exhaustive. Black (1962) lists four types. Along selected dimensions, *scale models* reduce or magnify the properties of the objects they represent with the purpose of reproducing, in a manipulable or accessible form, important properties of the original thing modeled. While scale models involve change of scale, *analog models* also involve change of medium while reproducing the structure of the original: the model and the thing modeled are isomorphic. *Mathematical models* are the formalized theories of social scientists in which the system modeled is projected upon the highly simplified and abstract domain of sets and functions that can be manipulated by means of mathematical reasoning. Finally, *theoretical models* are simplified systems or structures. Unlike scale models, they are imagined and described but not literally built. In contrast to mathematical models, the properties of a theoretical model are better known than those of the original subject matter that is modeled.

Achinstein (1968) distinguishes between three kinds of model: representational, theoretical, and imaginary. In contrast to Black's typology, there is no distinction here between theoretical (and imaginary) models on the one hand, and mathematical models on the other. What Achinstein calls *representational models* (for reasons that will become clear, this label is unfortunate; a better name would be 'material models' or the like) are three-dimensional physical representations of objects of interest, such as tinkertoy models of molecules, and engineering models of dams and airplanes. The model and the object represented by it are two distinct objects. Engineers call the objects represented by such models prototypes. The model may reproduce all (or only some of) the relevant properties of the object, using one scale uniformly for all properties (such as a model of a bridge in which length, width, and thickness are all reduced uniformly by the same factor of 100); or using different scales for different properties (such as a model of the planetary system in which the sizes of the planets and the distances between them are reduced by different factors); or the relationship between the model and the prototype may be one of analogy (such as using an electrical system as a model of an acoustic system).

A *theoretical model* of an object is a set of assumptions about that object rather than a distinct object. Examples are the Bohr model of the atom, the Crick–Watson model of the DNA molecule, Markov models of learning, and the multiplier–accelerator model of economic growth. Such models are often called mathematical models in the social sciences, as the assumptions of the model frequently are expressed using mathematical equations. Theoretical models characteristically describe an object by ascribing to it an inner structure or mechanism. It is by reference to this structure that theoretical models help explain the behavioral and other properties of the objects so described. A theoretical model in this sense can be understood as a simplifying approximation of the object that is useful for some purposes. The use of such a model characteristically involves the awareness and explicit acknowledgement that the real object is far more complex than its representation in the model: the theoretical model assumes away many complications while highlighting limited aspects of the object. This feature of theoretical models explains why typically it is possible to hold and use a number of different models of the same object: given their characteristic simplifications, they highlight different aspects of the object for different purposes. Theoretical models can be viewed as small-scale theories with a limited scope of application, drawing from broader theories and from systems of more general and fundamental theoretical principles. They are combinations of such general principles and more specific, locally applicable, auxiliary assumptions.

Finally, many *imaginary models* are similar to theoretical models in that they are constituted by sets of assumptions describing an object or system. The difference lies in the imaginary character of the former: the assumptions of imaginary models are not intended as true or even approximately true descriptions of the features of any real object. Imaginary models describe imaginary worlds. They entail counterfactual conjectures that reveal logically, physically, mentally, or socially possible properties or conceivable behaviors: the imagined object could be one way if it met the conditions laid down in the assumptions—but it does not actually meet them. Imaginary models typically serve as stepping stones directing scientists toward further investigations about the real characteristics of real objects. We could consider Max Weber's notion of an ideal type as being close to the notion of an imaginary model in Achinstein's sense.

Many models involve analogies and metaphors. Given that there are different kinds and aspects of the latter, this gives rise to different kinds of model. Hesse (1963) is a classic discussion of models and analogies. When considering a collection of billiard balls in random motion as a model for a gas, the suggestion is that gas molecules are analogous to billiard balls. This implies that gas molecules and billiard balls share some properties—constituting the positive analogy—while other properties are not shared—they are the negative analogy. The neutral analogy consists of those properties which we do not yet know are shared. Hesse then distinguishes two kinds of model, the first being the conjunction of the positive and the neutral analogy, while the second includes the negative analogy as well.

Harré (1970) proposes a refined classification between three types and further subtypes of models. *Homeomorphs* are models whose subject and source are the same. Scale models are one subtype of homeomorphs (further divided into micromorphs and megamorphs, depending on whether the properties are reduced or magnified). Another subtype consists of teleiomorphs that are improvements on their subjects by way of abstracting (subtracting irrelevant properties, e.g., as in maps) or idealizing (such as in the case of the fashion model). The third subtype is the metriomorph that represents a class by way of averaging, for example (such as the notion of the average family along some dimension of properties, such as the number of children). *Paramorphs* are models whose source and subject are different, thus they connect two or more domains with one another. They may be used heuristically, as in using electric networks as models of hydraulic networks, and in using the latter as models of economic networks; or to create causal hypotheses, such as when using bacteria as models of viruses. Finally, *protomorphs* are kinds of diagrams and geometrical representations. Diagrams of social networks serve as an example of such models.

These examples show that the ontology of models is not uniform: models can be made of material stuff, and they may be linguistic as well as pictorial. Indeed, this last class should not be ignored, as science operates with a variety of visual models: drawings, figures, diagrams, graphs, and other images. Much of causal modeling in social research employs such visual means of representation: various causal chains and loops are represented in terms of boxes and arrows. The use of such models for visual representation does not follow the same rules as the linguistic mode of representation. As soon as a visual model is translated into a mathematical model, the rules of its use change.

Some models are abstract entities, while some others are very concrete. Consider animal models in biomedical research. Under certain conditions, certain animals can be manipulated so as to use them as models for human beings. By experimenting with the animals, medically relevant information is generated about humans. Particular animals are concrete systems that are used as models. In general, any experimental set-up serves as a model of a non-experimental real world system. Such experimental systems are concrete rather than abstract entities. One can also think of numerical computer simulations in these terms: systems of equations are manipulated numerically with the help of a computer to acquire information about some real system that is modeled in such a concrete way.

There is a general sense in which models are constructed. However, a three-dimensional scale model is constructed in a difference way than a theoretical model: it is built, while a theoretical model is imagined and then described. An experimental model is similar to the scale model in this respect. The important difference between an experimental model and a theoretical model is that the elements of the former can be controlled causally, while in the latter, such control is forthcoming only by way of assuming that certain factors are absent, constant, or otherwise neutral.

The concept of model suggests that a model is a 'model of' something. Thus we have models of humans and models of social interaction, models of the atom, and models of the origin of the universe. We also have models of quantum mechanics and models of the general theory of economic equilibrium. In general, we may distinguish between models of theories and models of real systems. The scientific procedure also involves models of data that reduce the complexity of experiential materials to simpler and more manageable portions of information. Based on classifications, simplifications and idealizations of various sorts, sampling, data mining, and other techniques, these are models of the complete data. Models of data are necessary for the same reason for which models in general are needed: the complete data are too rich and complex to be of any use.

A model *of* something may sometimes also serve as a model *for* design or imitation, as in architecture and social thought. A miniature model of a house and a theoretical model of an institutional structure may serve as models for constructing a concrete house and a concrete structure of social institutions.

2. *Theories and Models*

Models and theories are viewed as being related in a number of ways, depending on notions of model and theory. It has been suggested that a major difference between a theory and a model is that scientists using either of these hold different attitudes towards them: They take a theory to involve the belief that the system it describes is really governed by the principles suggested by the theory, while such a belief is not involved in the use of models. Scientists take a theory to be (perhaps hypothetically) a true account of a given system, while various models can be used for different purposes in relation to that same system without any commitment as to their truth. One may refer to something as 'just a model,' whereas to characterize it as a 'theory' is to be less modest about it. Another traditional way of stating the idea is to say that, when using a model, the scientist claims that a system behaves *as if it were* as the model represents it, while, when using a theory, the claim is that the system behaves as it does because *it is* (or at any rate might be) the way the theory says it is.

In a similar vein, Achinstein's distinction between theoretical and imaginary models is based on the different attitudes of scientists: theoretical models do, and imaginary models do not, involve ontological commitments as to the reality of the entities and properties depicted. This suggestion implies immediately that different attitudes toward certitude and commitment do not define a theory–model distinction (but rather a distinction among models). On the other hand, Achinstein's distinction, too, is based on differential attitudes. This seems too stark: the differences in the relevant attitudes often seem more blurred. Scientists may not be in agreement regarding the ontological status of a given model. Such attitudes are also often not on–off matters, but rather matters of degree. Thus, no sharp dichotomy may be forthcoming. Moreover, these suggestions presuppose a realist outlook: on an instrumentalist account of theories, there is no difference of any sort, as everything would be an imaginary model. It should be added that, without further specifications, the as-if locution alone is unable to differentiate between the intended two attitudes.

Another popular account is in terms of specificity. A theory is an abstract and general statement about a number of generic entities and their key dependencies. Game theory can be considered a theory in this sense. The neoclassical theory of economic growth is another example. A theoretical model is a more specific and smaller scale version of the theory, involving various idealizations, simplifications and other auxiliary assumptions, and addressing specific issues. A theory serves as a prototype for the construction of such models. One theory can be specified in the form of many theoretical models, using different selections of variables and functional forms between them, for example. The prisoner's dilemma, battle of the sexes, chicken, and other 'games' and their further specific versions are such theoretical models. So are one-sector and two-sector models of growth, with exogenous or endogenous technological progress. An empirical model is one with parameters that can be, or have been, estimated in terms of empirical data. Experimental game models and econometric growth models are examples.

There are further, logically pretheoretic, elements that are often called models. They are world models or metaphysical models, such as models of individuals and models of society. They have the character of general presuppositions or underlying convictions that provide the most abstract conceptual frameworks for more specific intellectual exercises. These include various forms of individualism and collectivism, agency-structure models, visions of society as in harmony and in conflict, and of the development of societies as progressive or repetitive.

The above accounts often regard theory as consisting of statements. This idea has been challenged by those who hold so-called semantic or model-based accounts of theories. Consider an accessible version of such an account of theories as made of models (Giere 1988). Models are taken to be abstract and idealized entities that have only the properties ascribed to them by scientists. Thus scientists refer to planetary systems where planets are dimensionless mass points, and to harmonic motion such as that of a pendulum of a frictionless clock influenced only by a uniform gravitational force presupposing that the Earth is a perfectly homogeneous sphere. Models in this sense can be characterized by linguistic (and other, such as graphical) means, but are not themselves linguistic entities. Models lie somewhere between language and concrete reality.

It is characteristic of such abstract and idealized entities that they perfectly satisfy certain mathematical equations. Thus the simple harmonic oscillator perfectly satisfies the force law $F = -kx$ that serves as its equation of motion. Likewise, the model of perfect competition in economics can be considered an abstract and idealized system that perfectly satisfies 'laws' such as the first and second welfare theorems. The idealizations of the models are needed to ensure such a perfect fit. Indeed, models in this sense are constructed so as to fully satisfy the key claims of a theory. This way of putting it brings the idea close to the use of the term 'model' in meta-logic where a model of a formal theory is a structure that satisfies the axioms of the theory.

Note that Giere takes models to be abstract entities rather than anything concrete. Using such a model with highly idealizing assumptions, one can derive mathematically statements about the behavior of the abstract entity. The greater the similarity between the abstract system and the concrete system, the closer the fit between the behaviors of the abstract and concrete systems. Giere says he has derived the notion of model in this sense from physics textbooks. However, just as real systems are more complex than abstract ones, so is much of real scientific research more complex than its textbook 'models.' Many models used in science are concrete and do not allow for neat mathematical derivations.

Others challenge such views of theories-as-models and models-as-specifications-of-theories, arguing that models often enjoy a relatively independent role (Morgan and Morrison 1999). The construction of models draws on theories as well as on other sources (such as the data, technological design, and intuitive insight), but because models are relatively independent of each such source, they are able to serve as mediators between them. This applies both to theoretical models and to models of the data and experiments. This further emphasizes the possibility of having a number of (possibly mutually inconsistent) models of a system or phenomenon covered by a theory.

3. *Functions of Models*

It is important to put any thoughts about this issue in the plural: functions of models. Among other things, models help to explain and predict phenomena; construct, interpret and test theories; design and produce technologies, and (material and social) structures. This multiplicity of uses is yet another reason why scientists hold a multiplicity of models of the same system or phenomenon.

It used to be popular to conceive of models—models of theories—as providing interpretations for abstract scientific theories. Theories were taken to consist of formal, axiomatic systems in which theoretical terms—terms not referring to anything observable—figured prominently but lacked empirical interpretation. Models were regarded as visual or otherwise familiar systems that were isomorphic with the theories they help to interpret. Such iconic models provide interpretations for such formal calculi: thus, the system of billiard balls in a box is used to help understand the import of a theory of gases; and the analogy from the solar system is used for interpreting atomic theory.

Many of the earlier accounts of models viewed them as facilitating instruments of scientific cognition, rather than as its embodiments: models as heuristic devices, as aids to imagination, sources of inspiration, pedagogic devices, and the like. On the basis of substantive or formal analogies, models suggest directions for theory construction and for extending the application of a theory to new domains. In Gary Becker's controversial economics of the family, children are represented in analogy to durable consumer goods, thus rendering conventional economic principles applicable to family behavior. Models suggest new questions and new hypotheses as conjectural answers to these questions. The solar system model of the atom is an analog model where the nucleus is like the sun and the electrons are like the planets, orbiting the sun. This model has given rise to fruitful questions and hypotheses, such as those about the shape of the orbits of the electrons and the velocity of their motion. The computer model of the human brain has likewise provided tremendous heuristic services as a source of hypotheses about human intelligence.

One and the same model may serve the purposes of both inventing and testing hypotheses. Consider using animals as analog models in biomedical research whose primary subject consists of human beings. Thanks to the many obvious similarities between such animals and humans, these models provide heuristic guidance by inspiring ideas about the functioning of the human organism. Depending on how similar the underlying causal mechanisms in animal and human organisms are believed to be, analog models may also be used for testing hypotheses about the behavior of human organisms. Rather than testing the impact of a newly developed medicine on humans, it is tested on animal models, then the test outcome is inferred also to apply to humans. This strategy faces the same issues that are generally involved in the use of experimental models to study nonexperimental reality. Are the conditions inside and outside the laboratory sufficiently similar in relevant respects to justify the transference of conclusions from one to the other?

The conventional idea of using theoretical models for testing theories is based on the view of models as specifications of theories. Empirical testing also requires models of the data, those simplified and idealized modifications of the complete set of experiences into the tractable body of relevant evidence that can be compared with theoretical models. Because there are multiple models of a given theory as well as multiple models of the complete data, no test can be perfectly tight and conclusive. There is always slack between the theory and the complete data, thus a failure of a model does not entail the failure of the theory. This observation is further fortified by the idea of models as relatively independent mediators.

Some models serve as maps, describing configurations of phenomena with different scales and degrees of detail, depending on the purpose for which they are to be used. Some others serve to predict future phenomena by extrapolating past trends into the future. Other prediction models yield predictions of phenomena as responses to changes in exogenous variables. Yet other models are used to analyze the inner mechanisms of the generation of phenomena; often mathematical in form, such analytical models serve as theoretical machineries that are manipulated by the modeler in analogy to the causal manipulation of experimental machineries, with the purpose of identifying relevant causal mechanisms and examining their behavior.

Many models fail, and there may be a temptation to blame the very idea of modeling for this. But it is hard to think of modern science without models. Naturally, there are good models and there are bad ones, and many in between. Good models serve their purposes well, and bad models do not. A failure of a model is not because it is a model, but because it is a bad model for a given purpose.

4. *Models as Representations*

Given the multiplicity of types of model and their uses, one may ask whether there is anything that the various models have in common. A possible answer is that models are used to represent something beyond themselves. Representation has two related aspects: a model represents something else in that it resembles it in some respects, and in that it stands for that other as its 'representative.' Models can represent bits of the world as well as theories in these two ways. Models of X represent X and can be used instead of X itself to acquire information about X. One uses engineering models of airplanes to examine real—perhaps yet unbuilt—airplanes. Likewise, by studying the properties of theoretical models—with different degrees of imaginary contents—one may hope to learn about the real objects or the theories that they represent. One studies the model directly, and by doing so may learn indirectly about what the model represents. Thus, one may study the causal mechanisms of a real economic system by analyzing an imagined model economy populated by Robinson Crusoe and Man Friday; and one may study the biological mechanisms of a disease in human beings by experimenting with concrete (unimagined) rats. Many types of models are on a par in this respect—such as those that are concrete systems, those that are visualizable in terms of common experience, and those that consist of abstract mathematical formulas. What makes a model useful for its purpose is that it can be manipulated to draw informative conclusions about the ultimate target of study.

One may say, as Wartofsky (1979) does, that anything can serve as a model of anything else. This only requires that someone takes one thing to represent another thing in some relevant respects, where relevance is determined by the purpose of the representation. If the computer can be taken as a model of a human brain (and the human brain as a model of a computer) and a set of mathematical equations as a model of the Big Bang, so can a cookbook recipe serve as a model of moussaka, and Adolf Hitler as a model of evil. Models can be linguistic and nonlinguistic, abstract and concrete. One and the same object can be modeled by using a number of other objects. There are many things that can serve as models of the market institution, depending on the purpose of the model: a pair of scissors, a cobweb, a seventeenth-century painting of housewives buying freshly caught fish, a photograph of the New York Stock Exchange, the image of a telecommunication system, a geometrical diagram, or a system of differential equations.

In all such cases, one studies a complex phenomenon or system by representing it with a (much simpler) model. The model has far fewer properties than its subject, many of them idealized. The simple model serves as a substitute for the complex subject. It is within, or in terms of, the model that one recasts whatever questions one has about the complex entity to generate answers to these questions. The traditional philosophical issues about models are both difficult and inescapable. How do models relate to reality? How do the simplified questions and answers within a model relate to the complexities of what is being represented by the model? How do the manipulations of, and speculations about, models help us understand what they represent?

Consider models in one of the senses discussed earlier, as abstract and idealized systems that have only a limited number of idealized properties. It is not surprising that while statements about such models can be perfectly true, they can be also utterly false when applied to real, concrete systems. Real, concrete systems are far more complex than models and therefore behave in ways that cannot be truly represented by those statements. Interpreted as statements about real systems, the laws of science are false—and they remain false even after modifications such as from linear to non-linear equations. But other than this negative feature, how do model systems and real systems relate to one another? Giere suggests that models are representations that are connected to bits of the world by the relationship of similarity: models are similar or dissimilar to real objects in certain respects and to certain degrees. A further component—a theoretical hypothesis—makes claims about such respects and degrees of similarity. Unlike models, hypotheses are linguistic entities that refer to models and how models relate to real systems. Hypotheses in this sense can be true or false, depending on how well they succeed in their task. Models cannot be true or false, Giere believes, since they are not linguistic entities. But this is based on the unnecessarily restricted presupposition that truth bearers have to be linguistic. If we accept that truth and falsehood can be ascribed to any representations, we can think of a model as possibly being partially true (insofar as it is similar to the real system in certain respects), and as approximately true (depending on the degree of similarity).

In assessing the merits and demerits of a model, the two aspects of representation must be considered jointly. On the one hand, the model should serve as a useful representative of its subject, providing a tractable substitute system that is amenable to a systematic examination yielding definite conclusions. And on the other hand, the model should resemble, or correspond to, its subject in certain respects and degrees closely enough relative to the goal of its purported use. The art of modeling is a matter of striking a balance between these two aspects of representation.

See also: Graphical Models: Overview; Metaphor and its Role in Social Thought: History of the Concept; Narrative Comprehension, Psychology of; Narratives and Accounts, in the Social and Behavioral Sciences; Rhetoric

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U. Mäki

Moderator Variable: Methodology

Typically theoretical and empirical models in the behavioral sciences posit that independent variables affect dependent variables. A moderator variable is a variable, which is thought to temper or modulate the magnitude of the effect of an independent variable on a dependent one. Conceptually it is important to differentiate between a moderator and a mediator. A moderator is a variable that affects the magnitude of the relationship between the independent and dependent variables. It identifies the conditions under which, or the type of participant for whom, the effect is likely to be particularly large or particularly small. A mediator is a variable that describes the process that is responsible for the effect of the independent variable on the dependent one. It is a variable that is affected by the independent variable and in turn affects the dependent one, thus being responsible for the effect. (See *Mediating Variable*; also Baron and Kenny 1986).

1. Examples of Hypotheses Involving Moderation

Hypotheses about moderation are ubiquitous in the social and behavioral sciences. The following examples, taken from a variety of fields, provide illustrations. Each example consists of two sentences. The first hypothesizes an effect of an independent variable on a dependent one. The second sentence identifies a hypothesized moderator.

(a) Level of education attained affects lifelong earnings. This relationship is less strong for females than it is for males.

(b) Stressful life events tend to produce psychological problems. These effects are lessened if one has an extensive social support network.

(c) Some forms of instruction lead to better retention than others. These effects are larger among more able students.

(d) Exercise has pronounced health benefits. These benefits are more pronounced among older people.

Note in these examples that moderator variables can take on a variety of forms. They can refer to characteristics of the participants in the research (i.e., their gender, ability, or age); equally plausibly they may characterize the situations or environments which moderate the relationship between the independent and dependent variables. Additionally, their scale of measurement may be nominal (e.g., gender) or may vary more or less continuously (e.g., ability levels).

2. Conceptual and Analytic Issues in Testing Moderation

To say that one variable moderates the effect of another is equivalent to saying that there is a statistical interaction between the two variables. Accordingly, moderation implies interaction, although not all interactions involve moderating variables. The distinction is as follows: moderation means that there is a main effect of the independent variable plus an interaction between the independent variable and the moderator. Overall there is an effect of the independent variable, but the magnitude of that effect depends on the