Methods, Models and Revolutions

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This is a comment on "The Epistemology of Mathematical and Statistical Modeling: A Quiet Methodological Revolution," by J.L. Rodgers (American Psychologist, v. 65, January, 2010, pp. 1-12).

Rodgers (January, 2010) describes a quiet revolution that has occurred over the last decade as scientific psychologists have moved from null hypothesis statistical testing (NHST) to model testing as a way to evaluate the results of behavioral research. This revolution represents an important scientific advance for psychology and Rodgers does the field a great service by pointing it out and describing it so well. I would argue, however, that what Rodgers describes as a *methodological* revolution has actually been an *analytical* revolution in psychology.

The move from NHST to model testing represents a change in the way behavioral data is analyzed, not in the methods used to collect it. Indeed, there has been no methodological revolution in psychology, though I have argued that such a revolution may be needed (Marken, 2009). The argument for a methodological revolution is based on a modeling approach to understanding behavioral data (Runkel, 1990). So, while the move from NHST to model testing may not represent a revolution in methodology, it can pave the way for one.

The relevance of modeling to methodology shows up most clearly in the design of psychology experiments. Experimental design is currently based on an input-output model which views sensory input, i, as the ultimate cause of behavioral output, o. In mathematical form the model says that $o = f(i)$, where f() characterizes the causal processes that link input to output. According to the input-output model, the way to learn about the causes of behavior is to vary sensory input, i, under controlled conditions to determine its effect on behavioral output, o. Sensory input is typically varied indirectly by manipulating an environmental variable – the independent variable, IV, in an experiment – while behavioral output is measured as the dependent variable, DV (Levitan, 2002).

If the input-output model of behavioral organization is correct then an observed relationship between IV and DV provides a picture of f(), the causal path from input to output. If this model is not correct, however, then the observed relationship between IV and DV gives a very misleading picture of the causal structure of behavior (Powers, 1978). Therefore, the validity of current experimental methodology depends on the correctness of the input-output model itself. One piece of evidence regarding the correctness of this model is available thanks to the analytical revolution described by Rodgers (2010). Researchers now report their results not only in terms of the usual measures of statistical significance but also in terms of measures of the goodness of fit to the input-output model. Goodness of fit is measured as the proportion of variance in the DV that is accounted for by the IV using a form of the input-output model called the general linear model (Cohen & Cohen, 1983). A perfect fit occurs if 100% of the variance in the DV is accounted for by the IV. I have done a survey of the results of several recent experimental studies and found that, on average, the IV accounts for little more than 34% of the variance in the DV in these studies.

Another piece of evidence regarding the correctness of the input-output model comes from the observation that many behaviors, such as catching a fly ball, are clearly closed-loop; inputs (such as the sight of the ball) cause outputs (running) that have an immediate feedback effect on the inputs that cause those outputs (Marken, 1997). The input-output model is open-loop inasmuch as it assumes that output has no effect on input. So the input-output model doesn't seem to apply to closed-loop behaviors. This has not been considered a problem for research based on the input-output model because behavior in the typical psychology experiment appears to be open loop; outputs (DV) have no obvious effect on inputs (sensory effects of the IV).

Whether or not the behavior in psychology experiments appears to be open-loop depends to a large extent on what is identified as the input in these experiments. An open-loop model views input as the sensory consequence of variations in the IV. A closed-loop model views input as a *controlled* consequence of simultaneous variations in the IV and DV -- input being controlled in the sense that it is maintained in a goal state by the actions of the organism (Marken, 2005). The difference between these two views can be illustrated by a simple reaction time experiment where participants are asked to press a key when a tone comes on but not otherwise. An open-loop model would see the input in this experiment as the sensory consequence of the tone (IV). A closed-loop model would see the relationship between tone and key press as the variable the participant is trying to control.

The superiority of the closed- over the open-loop interpretation of the experiment can be seen in the fact that tones do not ordinarily cause key presses. Participants press the key when the tone comes on only if they have adopted doing this as a goal. The controlled input in this case is a logical variable, ”true” when the key is pressed after the tone and “false” when the key is pressed after no tone. The participant controls for keeping this input in the state “true”. When participants do this they will appear to be reacting to the sensory consequence of the tone but, in fact, they are controlling a logical variable. Their behavior will appear to be open-loop when it is actually closed-loop.

The modeling approach to data analysis suggests that closed-loop models may be more appropriate than open-loop models of organisms. This has revolutionary implications for methodology because the methods used to study closed-loop systems are quite different from those used to study open-loop systems (Marken, 2009). The methods used to study open-loop systems are the familiar methods of experimental psychology, which aim to determine the variables (inputs) that cause of outputs. The methods used to study closed-loop systems are based on those used in control engineering, which aim to determine the variables the system is controlling and how it controls them.

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