Behavioral Theory In Simulation:
Ambiguous Results From Simple Relationships

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Abstract
A system dynamics model of individual performance is developed and simulated. Performance, a behavioral factor, depends upon and influences emotional and cognitive factors: stress, mood, and motivation. Activation, found in both stress and motivation literatures, is treated separately. Each causal relationship is assumed to be simple and unambiguous. Analysis of the model output under a range of work conditions shows that ambiguous or complex relationships, and incorrect specifications, would be supported by traditional research. Complex relationships between stress, motivation, and individual performance emerge from model structure and interactions, rather than from assumed causality. This work demonstrates the benefit of simulation in theorizing when multiple factors operate in tandem.

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The situation of persons within organizations is complex, far more so than can be expressed in any simple theory (Simon, 1979). Behavioral, cognitive and personal factors interact in dynamic ways that include bi-directional causality (Wood & Bandura, 1989). Any variable of interest has multiple influences and is an influence of multiple others (Mitchell, 1997; Rafaeli & Sutton, 1989; Walsh, 1995). There have been countless calls to integrate and develop theory (Pfeffer, 1998; Sutton & Staw, 1995; Van Maanen, 1995; Weick, 1989; Whetten, 1989), but a grand unified theory of organizational behavior does not exist. It seems likely that one is impossible.

Just because no single theory can explain everything does not mean we should not be integrators. Though the review process favors publication of work that develops new direction in theory (Beyer *et al.*, 1995), practitioners need answers to basic questions (Hedrick *et al.*, 1993). We know a great deal about organizations (Miner, 2003); a great number of theories are well supported even if not entirely compatible. Yet though many processes have conflicting theories, often the effect of one variable upon another is the same across theory or robust to assumptions about process (Repenning, 2002). Certainly, enough is known to begin integrated models of factors of concern to real organizations.

There are many challenges to developing integrated theory. Research methods in the social sciences are typically static, optimized for isolating effects from each other, a tradeoff between generalizability and richness (Brinberg & McGrath, 1982; Creswell, 1994; Forrester, 2003). Interactive, dynamic, complex research is called for (Donovan, 2001), but even that might not work. Many effects involve hard to measure 'soft' variables that change over time. There is not yet a way to get a real time measure of such concepts as stress, mood, or motivation; and the definition of such concepts varies across situation and culture (Meyerson, 1994). Even if we were to have extremely good instruments suited to the situation at hand, the amount of data needed to discern dynamic patterns could be prohibitive for both the researcher and subject.

Simulation can provide a way past these difficulties. A simulation model represents a theory of how a particular system works (Lomi & Larsen, 2001) that can include hidden variables, update more frequently than data is available, and include the interaction of as many factors as the modeler desires. Yet unlike a purely narrative theory, a simulation model will include output that can be compared with whatever data is available. In essence, simulation can provide the discipline in Carl Weick's (1989) conceptualization of theory construction as disciplined imagining.

The purpose of this paper is twofold: to provide an example of theorizing with simulation, and to illustrate the limitations of quantitative methods. First, I will develop a model representing an integrated theory of individual performance as influenced by cognitive and emotional factors. This model will be both limited and provisional – applicable to a particular hypothetical situation only. Second, I will treat the model as "reality" and conduct experiments that show how traditional analyses could deceive the researcher even with unrealistically good data.

Though meant to be an integrative work, no model can subsume all possible causes and relationships in a setting as complex as organizations. This model will include three principal determinants of individual performance: stress, mood, and motivation. I have selected these three because they seem to have a clear logical relationship to performance and they span behavior, emotion, and cognition. Despite being well studied, they still present ambiguous or confusing results, possibly because they are interrelated (Seo *et al.*, 2004; Siders *et al.*, 2001; Sullivan & Bhagat, 1992; Weiner, 1982). The construct of activation plays a similar role in some stress and motivation theories (e.g. Mitchell, 1997; Schaubroeck & Merritt, 1997), so I will treat it separately.

Individual performance is clearly a principle concern to managers and organizational scholars. Performance is based on, but not identical to, behavior; both of these have multiple causes (Mitchell, 1997). Behavior, cognition, and emotion are related to each other and to performance in such a way that attempts to study one effect in isolation is likely to be misleading (Wood & Bandura, 1989). Since more variables are thought to affect performance than can be kept track of mentally, practitioners could benefit from a model that allows them to predict the effect of various policies. Thus individual performance is a suitable subject for the type of theorizing proposed.

Performance depends on and influences mood, motivation, and stress; all of these depend on past conditions; several are not directly observable. Models with multiple causes can be difficult to test but can be easily simulated (Lomi & Larsen, 2001: Introduction). I propose that a model that makes relatively simple assumptions about the causal relationships between an individual's performance, mood, motivation, stress and activation will display complex behavior, including the sometimes inconsistent findings of performance research.

Modeling as Theorizing

One possible explanation for the difficulty in crafting integrated theory, and the ambiguity of evidence, is the adequacy of research methodology. The inherent complexity of social systems means that selection of a research program presents certain tradeoffs (Hedrick et al., 1993). A qualitative, ethnographic, participant or action research agenda can express almost endless complexity but it is hard to use qualitative research to make predictions or analyze policy. Quantitative research can result in a model to make predictions, but statistical techniques are limited to static, linear models with simplifying assumptions (Creswell, 1994; Tashakkori & Teddlie, 1998).

Descriptive and predictive validity simply place different demands on the research process (Brinberg & McGrath, 1982).

'Disciplined imagining' (Weick, 1989) can take theory beyond the observed conditions, but often the only measure of validity is whether the theory rings true. Simulation can be considered an aid to both imagining and discipline, and an enhancement to validity. Human beings are simply bad at projecting experience beyond the static, linear boundaries of simple systems (Deihl & Sterman, 1995; Tversky & Kahneman, 1974). Computer models are not so limited. Simulation can be a valuable tool in applying complex theory to test policy, make predictions, and design systems that are robust to adverse events.

Computer simulation models are collections of assumptions, which may or may not hold up in practice (Sterman, 2002). However, all models of social systems depend on assumptions (Morecroft, 1983), and all sensemaking depends on models, whether mental or formal (Simon, 1979). Several filters operate before even the most basic data are processed (Tversky & Kahneman, 1974), much less before decision or interpretation (Walsh, 1995). Even the most empirically driven work depends upon the (often implicit) assumptions of its measurement instrument and analysis techniques (Creswell, 1994). With a formal simulation model, the assumptions are made explicit, and can be challenged and tested.

System dynamics (Forrester, 1961; Sterman, 2000) is a method particularly suited to problems characterized by feedback, accumulation, non-linearity and history dependence. The interactions of behavioral, cognitive, and emotional factors in relation to individual performance have these features. Motivation depends on past accomplishments, stress builds up, good or poor performance feeds back to influence its causes. Organizational performance frequently suffers because feedback and temporal processes are misjudged (Sastry, 2001). From the return of off-lease cars interfering with new car sales (Sterman, 2000: 42-54), to implementation failure of useful improvements (Repenning, 2002), system dynamics has helped to expose the dynamic causes to organizational problems. An elucidation of the feedback structures through simulation can aid in organizational understanding of performance and other factors.

To create a system dynamics model of individual performance, I translate relationships found in the organizational theory literature into equations. Following the example other system dynamics modelers (e.g. Rudolph & Repenning, 2002; Sastry, 1997; Sterman & Wittenberg, 1999), I use the substance and the text of articles as data. The descriptive sections of both theoretical and empirical works can be as valuable as the substantive findings, especially as terminology may vary between author, and theory specification may not be in a form directly translatable into differential equations. This process has been compared to grounded theory (e.g. by Rudolph & Repenning, 2002), in that the information found in existing work is treated as data for theory development, thus generating new theory from existing theory (Glaser & Strauss, 1967). The model variables, structure, and behavior are not assumed *a priori*; rather they emerge in an iterative process as ideas from the literature are incorporated.

Behavior, Cognition And Emotion

The starting assumption of this work is that people in organizational settings have cognitive, emotional, and behavioral factors. These three divisions are neither clearly bounded nor isolated – factors may span or have effects that span more than one area. The factors include both states, which have some persistence, and processes, which are more immediate. The interactions between states and processes form feedback loops that can balance or reinforce changes. In the resulting system, both observable behaviors and unobservable internal states have multiple causes, are in turn the causes of multiple effects, and evolve over time. The conceptual map of such a system is shown in Figure 1.

Researchers have addressed the relationships between cognitive, emotional and behavioral factors using different approaches. These investigations have used different names and appeared within performance literature, motivation literature, emotion, stress and commitment literatures. The constructs that emerge to form a model of individual performance are the cognitive and emotional factors: motivation, stress, activation, and mood; and their behavioral consequences effort and accuracy. The paragraphs that follow include descriptions of each concept; details on their formulations follow in the Model Structure section.

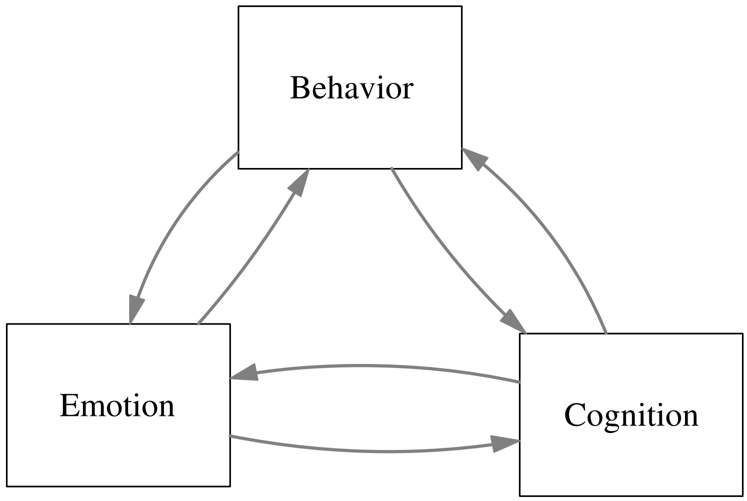

Figure 1. Conceptual map of performance factors.

Motivation relates to the choice of voluntary action (Mitchell, 1997), and affects the way expectancy and equity are perceived (Scholl, 1981). Motivation causes performance to rise in concert with such factors as goal commitment and past performance (Locke *et al.*, 1988), effort accuracy and duration (Mitchell, 1982) and attention to goals (Mitchell, 1997). Motivation is closely related to emotional factors (Locke et al., 1988; Scholl, 1981) and is partly the result of past experience (Kanfer & Heggestad, 1997; Wood & Bandura, 1989). In addition to situational factors, motivation depends on dispositional factors that are either permanent or change slowly (Kanfer & Heggestad, 1997; Mitchell, 1982). Emotional factors may be mediators in the link between experience and motivation (Seo et al., 2004). The words motivation or goal commitment can refer to a complex of constructs including both the state of being motivated and the processes by which perception is translated into action or attention (Kanfer & Heggestad, 1997). I therefore include the variable "Motivation" as a state and embed it in the processes involving action, attention, and feedback from past performance. I represent disposition as a "Permanent Motivation" which does not change over the course of the simulation.

Stress has a variety of operational definitions and theorized relationships within existing research (Sullivan & Bhagat, 1992). The actual experience of stress has been found to depend upon cultural factors (Meyerson, 1994). Stress is described as building up or accumulating in response to stressors (Cordes & Dougherty, 1993; Meyerson, 1994;

Schaubroeck & Merritt, 1997) and as interfering with cognition and sensemaking (Staw *et al.*, 1981; Weick, 1993). People recover from stress when stressors are removed (Meyerson, 1994). This dependence on perceived conditions and effect on sensemaking lead me to treat the variable "Stress" as a cognitive state, though it clearly has an effect on emotional states. Stress builds up in response to pressure and is relieved in the absence of pressure.

Interference with cognitive processes provides a logical reason why stress should lower performance. A sometimes positive relationship between stress and performance has been observed, dating back to Yerkes and Dodson's (1908) work on training mice. However, when stress is theorized to cause an increase in performance, the language used is more evocative of motivational processes than of stress (e.g. Edwards, 1992; Schaubroeck & Merritt, 1997; Sullivan & Bhagat, 1992; Yerkes & Dodson, 1908). Sullivan and Bhagat (1992) suggest that the ambiguous results arise from studying stress in isolation and ignoring its evolution over time. Since a level of pressure, activation, or anxiety is common to the processes of motivation and stress, I treat it separately as the variable "Activation" (below). I explicitly assume that stress itself has only detrimental causal effects on performance and emotion, and suggest that an association between moderate stress and higher performance will arise from the interaction with other factors.

A common theme in several of these treatments is activation. It is considered all of or part of or related to stress (Schaubroeck & Merritt, 1997), motivation (Mitchell, 1997), mood and emotion (Rafaeli & Sutton, 1989). Names for this concept include activation, anxiety, arousal, attention, demand, dissatisfaction, intensity, pressure, stress. In models, it has been formulated as being the difference between desired and perceived states (Edwards, 1992), or as caused by such a difference (Rudolph & Repenning, 2002); activation is invoked to explain why people act to close such a difference (Kahneman & Tversky, 1979). The frequency and variety of the use of activation suggests that it is a central construct that can be experienced in a variety of ways. It seems to have interesting relationships – causal, moderating, mediating – with all three of the performance variables considered here. The complex relationships may be why what is motivation to one author is stress to another, and why variables can have both positive and negative effects on performance. In this model, I treat "Activation" as a separate variable. It is conceptualized as a malleable and immediate cognitive state, caused by the demands of the job and the processes of attention to goals. Activation causes stress and interacts with both stress and motivation in affecting performance.

Among emotional constructs, the simple description of mood or affect is most closely linked to individual performance. Mood is seen as contributing to performance (Seo et al., 2004; Wright & Staw, 1999), and is strongly affected by perceptions of performance (Fisher & Noble, 2000), unlike specific emotions, which are seen as more distal (Elsbach & Barr, 1999). There is a long term or dispositional component to affect (Judge & Bono, 2001; Wright & Staw, 1999) against which the immediate state fluctuates (Fisher & Noble, 2000). Mood is related to motivation (Kanfer & Heggestad, 1997) and affected by stress in performance settings (Douthitt & Aiello, 2000). Mood may be a mediator in the feedback between performance and motivation (Cron *et al.*, 2002; Fisher & Noble, 2000). Affect has both direction and intensity(Seo et al., 2004); I specify the variable "Mood" as a state that can take either positive or negative values to capture direction and strength. Mood is influenced by stress and performance, and in turn influences motivation. Mood tends toward its permanent or average state, called "Disposition".

Many consider that the behaviors that lead to individual performance are the product of two concepts: some kind of intensity or quantity (here called effort) and some kind of direction or quality (here called accuracy) (Edwards, 1992; Judge & Bono, 2001; Mitchell, 1982; Seo et al., 2004). Aggregations of similar concepts are frequently used in system dynamics models at higher levels of analysis (e.g. Rudolph & Repenning, 2002; Sastry, 1997). The variable "Effort" is assumed to be the consequence of motivational processes, while "Accuracy" changes in response to stress.

Individual performance itself is dependent on the work context (Mitchell, 1997; Siders et al., 2001). The model must therefore include a simulated work environment, which is explained in detail in the Model Structure section below. The most direct measure of individual performance in this setting is the variable "Work Completion Rate", the product of effort and accuracy. Goals can be set for completion rate which can raise activation in conjunction with motivational processes. The level of backlog or work in progress is also affected by performance, and forms the measure of job demand, which causes activation directly.

Combining these assumptions forms the complete model, as shown in the causal diagram of Figure 2. Activation, a temporary and immediate state, is caused job demands and the attention to goals. Activation causes stress to build up. Activation and stress together degrade accuracy, while activation and motivation together tend to enhance effort. Stress, mood, and motivation are somewhat more stable, but are also affected by feedback processes. Good performance improves mood, poor performance and high stress worsen mood; mood in turn can affect motivation.

A normal control mechanism forms a balancing loop: if performance is too low, increased activation mediated by motivation leads to increased effort, and increased performance. Counteracting this effect is a reinforcing loop: if activation is too high stress builds up, causing accuracy to fall. The links from performance to mood, motivation, and stress interact with the other feedback and form both reinforcing and balancing loops, but with longer delays.

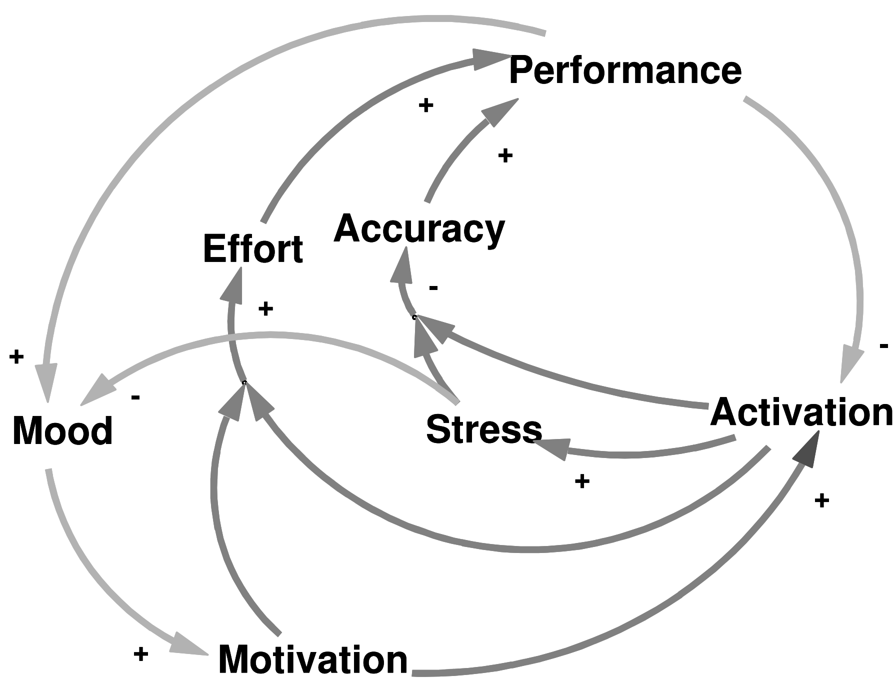

Figure 2. Causal loop diagram.

Model Structure

The model stock and flow structures are shown in figures 3 through 6. The model is implemented using the Vensim® software (Ventana Systems, 2002); the complete model is available from the author, or as a supplementary file on the conference website (www.systemdynamics.org). In most quantitative work, the functional form of the relationship between variables is assumed implicitly and dictated by the estimation technique selected (Crown, 1998). Nearly all such models are linear and the assumptions are made without explanation (March, 2001) despite the fact that linearity is not usually a good assumption (Sterman, 2002). The organizational theory literature is mostly silent regarding the details of relationships between variables, so the assumptions I make regarding functional form are based more on systems theory and modeling practice than on organizational theory.

An observation on scale is appropriate. The important constructs in this model are either unobservable (Mood, Motivation) or of arbitrary measure (Work in Progress). The units of the constructs and the scale of their relationships are therefore also arbitrary. The model is specified so that it is in equilibrium at "normal" conditions and can display various theorized behaviors over the permissible range of inputs. The arbitrariness of units places some limits on interpretation. It is not possible to say a particular phenomenon happens at a particular number of tasks per day; rather that as work rate increases there comes a point where the behavior changes. As noted above, the model is still valuable for generating insights even if it is not able to calculate an optimal work rate for a real world situation.

The Behavior section of the model, shown in Figure 3, represents the physical flow of work and the measures of performance. Tasks become available and accumulate in the stock Work in Progress. Work Completion Rate is the product of Effort and Accuracy, but is limited by the total amount of work available to be accomplished (Availability Limits). Accuracy and Effort are determined by the effects of Motivation, Stress, and Activation, multiplied by their normal values. If Work in Progress becomes too high, the Backlog Limits function feeds back to keep backlog between zero and ten times its normal value.

Work Completion Rate is compared to the Normal Backlog, to determine the effect on Activation; Perceived Completion Rate is compared to Work Rate Goal to determine the effect on Mood.

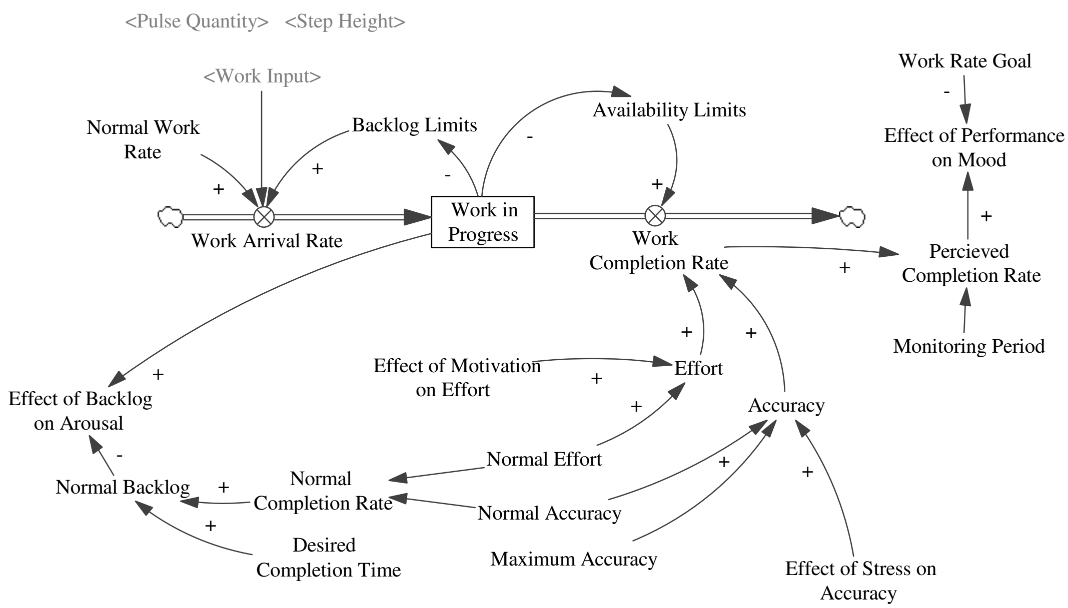

Figure 3. Behavior: work stock and flow.

The Cognition section, Figures 4 and 5, has three stock structures: Activation, Motivation, and Stress. Each stock is zero or positive; there is no meaning to a negative value. Activation has the shortest characteristic response and adjustment times of any stock in the model, and represents the most immediate cognitive response. Activation responds directly to Backlog, so that a normal Backlog results in a equilibrium level of Activation, while high or low Backlog adds Activation or allows it to fade. This represents activation in response to the task environment (Mitchell, 1982: 84). Activation is also affected by Motivation, which moderates the magnitude of Activation due to backlog.

Stress has adjustment and response times intermediate between Motivation and Activation. Stress responds linearly to Activation. Stress takes time to build up and even longer to be relieved, but absent Activation, Stress fades to zero. Once Stress builds up, it has a negative impact on Mood.

Motivation is longer lasting, and absent other effects tends to approach Permanent Motivation, here considered a constant, representing the dispositional component of Motivation (Mitchell, 1982). Very good or bad Mood can, over time, build up or erode Motivation, representing an affective experience effect on long-term behaviors(Seo et al., 2004).

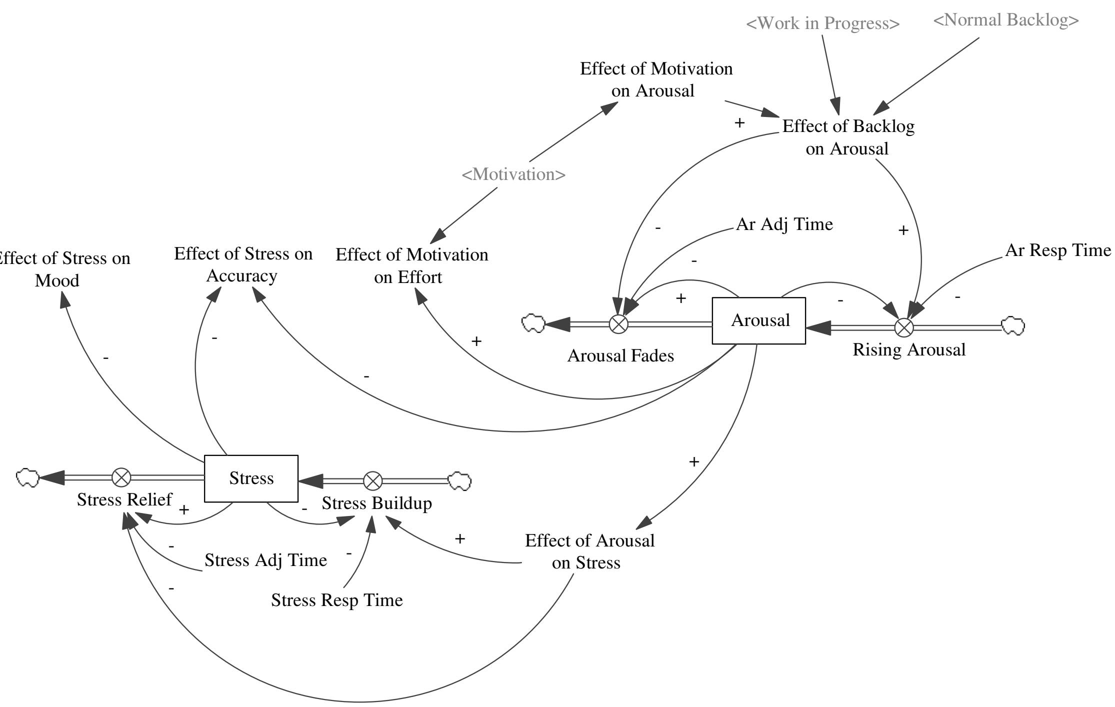

Figure 4. Cognition: Activation and Stress stock and flow.

The cognitive effects on behavior are all interaction effects, depending on Activation times Motivation or Activation times Stress. The effects are multiplied to determine Effort and Accuracy – therefore equilibrium levels yield an output of one. Motivation affects Effort, Stress affects Accuracy.

The Emotion section, shown in Figure 6, centers on Mood, which can be positive or negative. Absent other effects, Mood tends to approach Disposition (Wright & Staw, 1999). Mood can be affected by Performance (Cron et al., 2002) and Stress (Cordes & Dougherty, 1993). The Effect of Performance on Mood depends on the ratio of Perceived Completion Rate to its Goal; this forms part of the feedback from past performance to Motivation (Seo et al., 2004; Wood & Bandura, 1989)s.

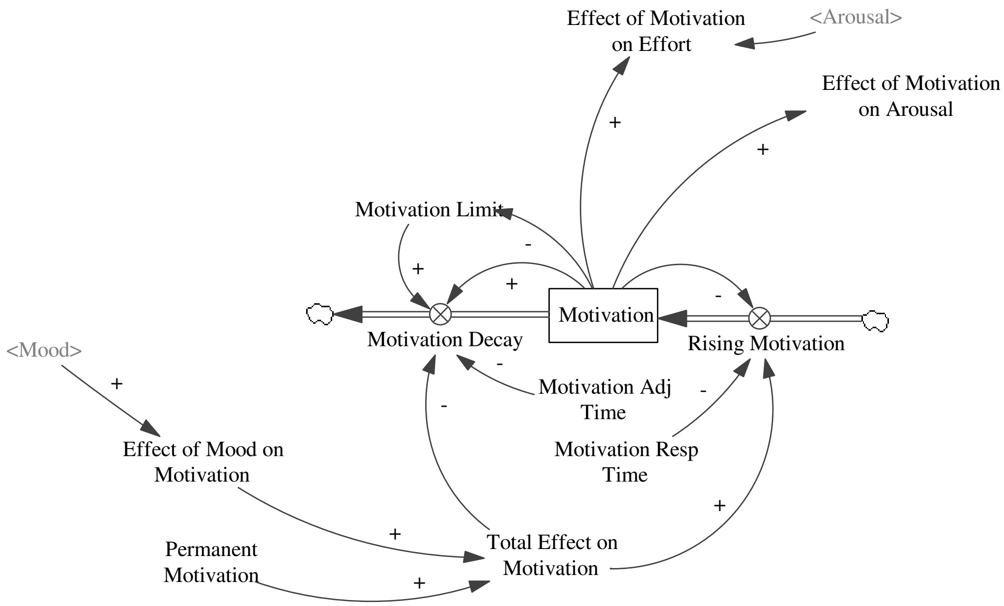

Figure 5. Cognition: Motivation stock and flow.

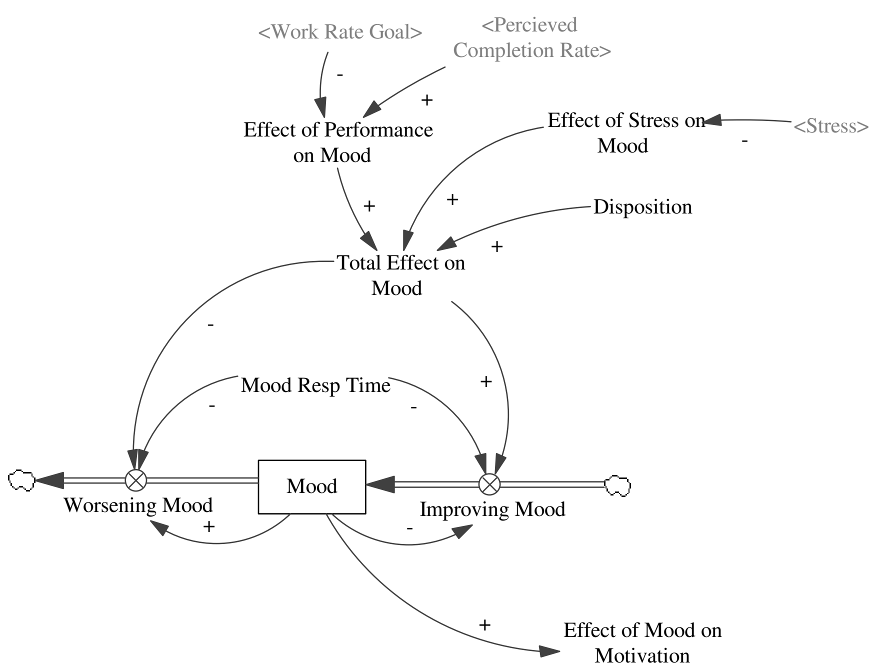

Figure 6. Emotion: Mood stock and flow.

The model structure also includes Inputs to test the person's response to various events and policies. The Work Input function changes Work Arrival Rate to test either a pulse (a one time arrival of a number of tasks) or a step (a permanent change in the rate of task arrival).

During model construction I specified the relationships with various functional forms and scale factors, in order to test for sensitivity of assumptions. While a complete sensitivity analysis is beyond the scope of this paper, the model is robust to most plausible changes to changes in specifications; that is, changing the assumed relationships to other possible relationships does not change the overall findings. There are some exceptions, which highlights that these results rest upon some reasonable but untested assumptions. These represent boundary conditions that limit the applicability of this particular model.

First, there exists some amount of increased backlog that does not cause a reduction in Accuracy. Without this assumption the model indicates a person working at maximum capacity, and any added work leads to collapse. Second, the worst degradation due to high Stress has a greater magnitude than the benefit of high Motivation. Without this assumption performance remains unrealistically high. Third, the time constant Motivation Response Time is longer than Stress Response Time. The model displays different (although qualitatively similar) modes of behavior if Motivation tends to change faster than Stress. The first two critical assumptions are not inconsistent with the literature reviewed above and are consistent with personal experience. The third is also consistent with experience.

The model is initialized in equilibrium, which occurs at 45 tasks/day, 50 task/day Effort times 90% Accuracy; a 45 task Work in Progress; normal Activation, Motivation, and Stress of 1, and neutral Mood. Simulations operate over 120 days of model time; no attempt is made to model variation in workweek or vacation.

Model Behavior

I expose the "subject" to two types of stressors: one-time assignments and permanent increases in workload. For each type of stressor, the magnitude of the change varies over a range sufficient to show the different behavioral regimes. The figures below show performance for the full range of changes. These three-dimensional graphs plot performance (Work Completion Rate) on the vertical axis against time (in Days) on the horizontal axis, with magnitude of change along the oblique axis.

The response of the subject's performance to one-time assignments of various sizes (in days worth of work) is shown in Figure 7. Relatively small assignments cause barely any stress at all, but the rise in activation motivates our subject to increase effort. The improved performance causes a sense of accomplishment, and mood improves very slightly, very briefly. Performance oscillates slightly as things get back to normal. In larger assignments, stress builds up and accuracy suffers. Even though backlog is falling and effort remains high, performance dips, and at this point one of two things can happen. If performance is still higher then its normal level, the work backlog is cleared, and the negative effects of stress diminish. There is a final surge in performance and the subject catches up. If, on the other hand, performance dips below its normal level before the assignment is completed, the effects of stress overwhelm those of motivation. Backlog builds up to its maximum, and the subject works with a permanently full inbox, permanently high stress, bad mood and poor accuracy, expending maximum effort until motivation begins to decay.

Figure 8 shows the response of individual performance to permanent increases in workload (in percent change). For this type of stressor there are just two types of response. In all cases, activation and effort rise in reaction to rising backlog, and for both modes, peak performance is higher and sooner for greater workload. But for smaller increases in work, backlog levels off. Although backlog, activation and stress are permanently higher than they were, the increased performance has a lasting positive effect on mood. Larger increases in workload produce higher peak performance, but it cannot be sustained. As stress builds up, performance declines slowly at first, then it plummets. Backlog builds to its limit, mood becomes so bad that motivation begins to fall. Once again, the subject becomes a stressed-out, unhappy, unproductive worker.

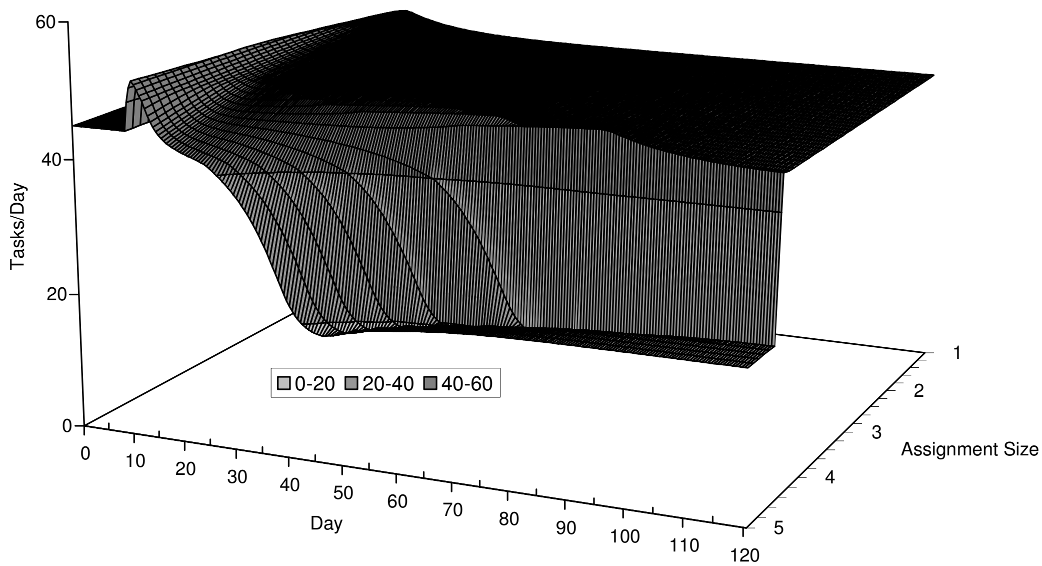

Figure 7. Response to one-time assignments.

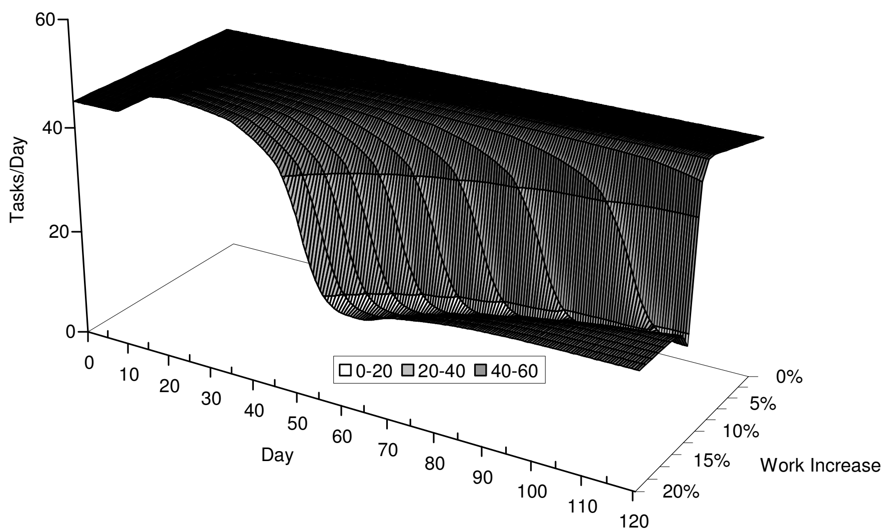

Figure 8. Response to permanent change in workload.

These results mirror the rich and ambiguous relationships that have been found in organizational research. This model is therefore a plausible alternative to other theories of performance. There are, unfortunately, significant barriers to performing more rigorous theory testing in this context. This model was developed as theory from theory (Strauss & Corbin, 1994) and would have to be significantly modified in order to apply to any particular empirical situation. As I have applied it here, system dynamics is a tool for theorizing rather that theory testing (Sutton & Staw, 1995; Weick, 1995); statistics would be the appropriate testing methodology (Sterman, 1984). But the ability to get output from the model does provide the ability to get additional insight into theorizing.

If the system I modeled here were a real person in a real organizational setting, the simulations presented would be the equivalent of data from an absolutely perfect experimental design. The subjects are identical in every way, with the only variation being assignment to treatment condition (workload change or assignment size); there would be no need to control for confounding variables. If we attempt to discern the relationships between variables from analyzing the model output, would we re-create the model or be deceived?

First, I will analyze what would be realistically observable data. Figures 9 and 10 show Work in Progress (WIP), as a reasonable proxy for stress, versus Work Completion Rate (WCR) as the observable performance. Each plot has several cross sections in time, with each point representing a different level of the treatment variable at that time. Figure 9 is for one time assignments, figure 10 for permanent changes in workload. The two kinds of experiments have different evolutions over time, and the pulse type shows a large transient behavior in the first week. Yet after the transient and for the entire step type experiment, all the points fall along the same inverted "U" shaped curve. Without knowing the actual specification, it seems that there is a consistent relationship between WIP and WCR. It would be good practice to test whether the upward sloping portion is due to motivation or the direct effect of stress. A regression using Effort as an observable proxy for motivation is shown in Table 1.

Table 1. Regression model of Performance.

Variable	Constant	WIP	WIP^2	Effort
Coefficient	47.4	0.127	-4.10×10^{-4}	-0.138
Std. Error	0.667	3.07×10^{-3}	6.60×10^{-6}	1.47×10^{-2}
R^2	0.997			
d.f.	143			

Note: all coefficients $p<0.001$

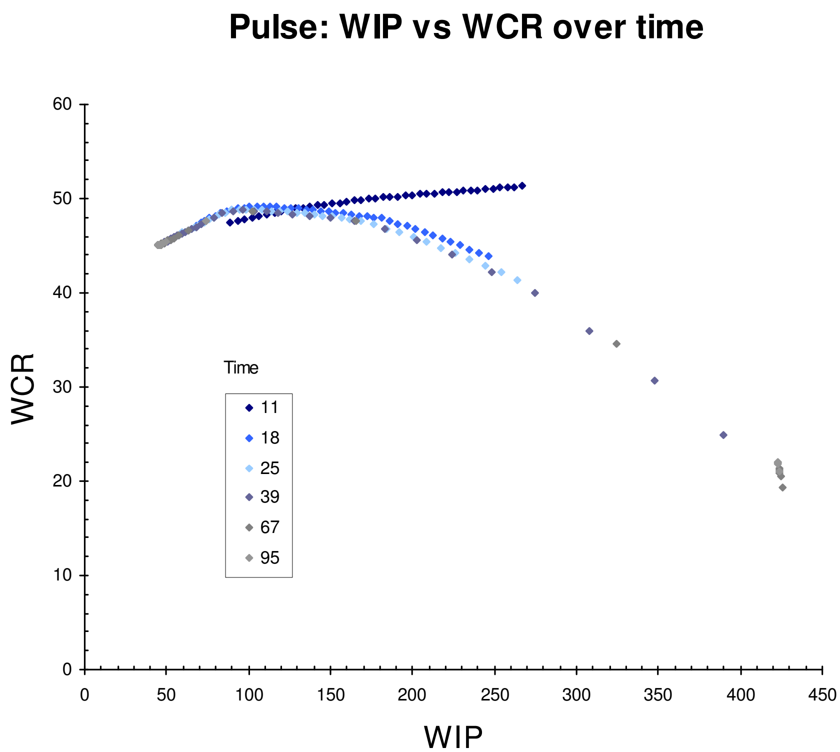

Figure 9. “Performance” versus “Stress” for one-time assignments.

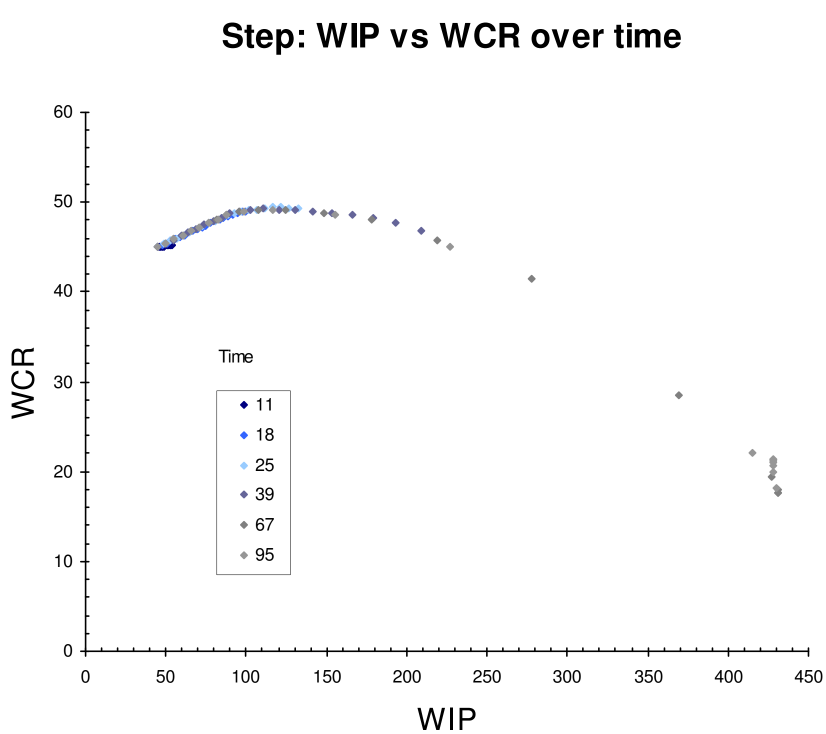

Figure 10. “Performance” versus “Stress” for permanent change in workload.

In the model effort is proportional to performance and does isolate the effects of motivation, and increasing stress always degrades performance. Yet by this estimate stress has an inverted U effect on performance. It also gives the wrong sign on the coefficient of effort – it should be exactly one. The regression statistics indicate excellent support for this incorrect model, with high R^2 and all coefficients discernable above point one percent. This would lead one to drop effort as a measure of motivation, or come up with a contingency model of motivation, or some other incorrect conclusion.

With simulation however, we need not rely on proxies. The following use the actual values of variables and closer approximations to the actual functional form, yet the estimations still give deceptive results. Table 2 shows the result of ordinary least squares regressions testing two models, one assuming Performance is an additive function of Stress*Activation and Motivation*Activation (as well as their squares), and one assuming Performance is a multiplicative function of Activation, Stress and Motivation each raised to an exponent. The latter specification is closer to the model assumptions. The best fit additive model includes upward and downward sloping sections for both Stress and Motivation. The exponents on the multiplicative model are contrary what should be found: the exponent on Stress should be negative, magnitude greater than one while the exponent on Motivation should be between zero and one.

All of the above estimations have excellent fits to the data, with coefficients of determination all above 0.9. This is as close to definitive proof as one gets in the social sciences, yet each estimation 'proves' something patently false.

Table 2. Interaction models of Performance.

Coefficient	Additive Model	Exponent	Multiplicative Model
Stress*Activation	0.75 (0.40) †	Stress	0.17 (0.067) *
$(\text{Stress*Activation})^2$	-0.096 (0.012) **	Motivation	2.19 (0.075) **
Motivation*Activation	3.04 (1.41) *	Activation	-0.093 (0.060)
$(\text{Motivation*Activation})^2$	-0.14 (0.092)		
Constant	41.31 (0.97) **		44.0 (1.01) **
R^2	0.998		0.974
Df	37		37

† $p < 0.1$ * $p < 0.05$, ** $p < 0.01$

Discussion

Given the unobservable nature of some variables, it would be difficult for a manager – or even the worker in question – to determine which trajectory in Figure 8 above the worker was on. Two weeks into the change, and employees on either side of the threshold have slightly higher stress and slightly positive mood. The value of this analysis is not to show that a 10% increase in work is safe but that a 12% increase leads to collapse. As mentioned above, the level and relationship scales are arbitrary, and would need to be calibrated for each individual. The contribution of this analysis is that the existence of such a breaking point would not be obvious from any one body of theory, and would be impossible to determine by most research methodologies.

Motivation theories predict that motivated individuals will increase performance in the face of challenge. Stress and burnout theories predict that increasing workload degrade performance. A laboratory experiment or an *in situ* observational study could sort subjects into those that break down and those that recover from a stressor, and document the characteristics of each group. But only a simulation model can subject the same subject to a variety of conditions, changing only one factor at a time, or as many factors as can be imagined, to determine the possible responses and the indicators thereof. Assumptions, embodied in constants or functional specifications, can be easily changed to find how sensitive policy implications are.

A stress researcher presented with data like those above could assume an inverted U-shaped response of performance to stress, and regression analysis would support that hypothesis. More sophisticated methods, looking at more data, using whatever proxies or instruments for stress and performance, a qualitative or quantitative stress researcher would have to find that a complex, curvilinear, contingency theory of stress was supported. Similarly, a motivation researcher would be forced to adopt a complex theory of motivation, and so on. Perhaps a theorist might integrate their findings, and suggest that the subjects have both a curvilinear response to stress and a contingency response to motivation, when in fact neither is occurring. Multiple processes are occurring simultaneously, but each relationship is simple.

I do not suggest that all other research methods are misleading. This model rests entirely on the writing and empirical findings of other researchers, most of whom were examining a particular relationship or a single subject area. The problem is that using statistics for theory testing depends critically on the quality of theory construction. There are two modes of deception depending on how we test and what variables we measure. First, because it is a interactive system we can get incorrect estimates and specifications that fit the data well. This makes it hard to proceed by aggregating separately observed results. Second, we can get very good support for static models. The build up, delay, and feedback are not always apparent in the data, even when looking at a lot of data changing over time. Since the real world probably is filled with feedback and accumulation, empirical support should be considered tentative. We may be faced with argument in favor of dynamic models for conceptual reasons when static models seem to work perfectly well. Good theory not only fits data, but is the plausible result of a well disciplined imagination. Simulation modeling is a useful technique in conjunction with other research strategies where such dynamic relationships might occur.

This is a first step, and as such other features can be added to the model as theory develops. The model simulates only a relatively short time, and so treats goals and dispositional factors as constants. A longer-term model could include dynamically set goals, based on motivation; test whether baseline mood, motivation, and stress are in fact fixed; model improving ability with experience. The structure can be repeated to simulate multiple people interacting, adding task dependency, emotional expression etc. While there is the ability to expand into new theoretical areas, not every piece of organizational theory can be expressed in the same model.

However, this analysis contributes to theory building in two ways. First, as an integration of theory this model can provide a base for both practice and research. The model can be tailored to any setting by substituting the actual production process, measures of performance, scales and functions as observed, and thereby serve as a tool for decision making. In a research setting, features can be added or altered as pieces of theory are brought in and in iteration with qualitative or quantitative data. It can be used in conjunction with data analysis, by simulating what relationships should be found between variables actually measured if hypotheses are to be supported. It suggests high leverage areas of research, such as identifying ways to monitor those indicators that prefigure system problems.

Second, this work displays techniques for building models of organization science theory – or social science theory in general. Some modeling approach is probably appropriate for nearly any theory, and new approaches may be generated as need arises. Ultimately, the discipline and practice can both benefit when theory, data, and simulation build on each other in the generation of knowledge.

Conclusion

The complex relationships between stress, motivation, mood and individual performance arise in this model because there are multiple processes acting simultaneously, not because the causal relationships are themselves complex. This suggests that an integration of parsimonious theories can explain the observed complexity of organizational life at least as well as individual but more complicated theories. A model of individual performance, where stress and activation together lower performance, while motivation and activation together raise performance, displays realistically complex behavior when multiple feedback processes operate simultaneously. The techniques of simulation modeling provided the discipline to create integrated theory that could not have been imagined unaided.

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