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Personality, Motivation, and Performance: A Theory of the Relationship Between Individual Differences and Information Processing

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We introduce a model to relate the personality dimensions of introversion–extraversion, achievement motivation, and anxiety to efficient cognitive performance. We show how these personality dimensions in combination with situational moderators (e.g., success, failure, time pressure, incentives, time of day, and stimulant drugs) affect the motivational constructs of arousal and effort. We propose a general information-processing model that accounts for the systematic effects of these motivational states on certain task components (sustained information transfer and some aspect of short-term memory). We combine empirical generalizations about task components in a structural model and derive testable predictions that differentiate alternative motivational hypotheses.

There are two major approaches to the study of human intellectual performance. The first focuses on the effect of personality and individual differences, and the second attempts to develop general laws of cognitive psychology or information processing. Although these two approaches rarely are combined, it is difficult to find an example of cognitive performance that is not better understood by a combination of both areas. In this article we propose a theory that integrates these two fundamentally different paradigms.

We believe that theoretical and empirical work on at least three personality dimensions poses a problem for anyone interested in the relationships of personality to efficient cognitive performance. These three areas of personality (introversion–extraversion, I/E; achievement motivation; and anxiety) have been shown in a number of studies to be relatively independent. Furthermore, research in all three areas has dealt with the situational and motivational determinants of efficient cognitive performance. What is particularly interesting is that each of these three dimensions has been shown to have a complex relationship to performance. High levels of introversion, achievement motivation, or anxiety are sometimes found to lead to better perfor-

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mance, whereas at other times they are found to lead to worse performance than are lower levels on these dimensions.

Perhaps even more interesting is that, although these dimensions are relatively independent statistically,[1] theoretical discussions of each of these areas are very similar. Each dimension is related to an underlying dimension of motivation (sometimes referred to as arousal, sometimes as drive, or sometimes simply as motivation) that, in turn, is then related to performance. In all three cases, motivation is thought to be a primary determinant of performance. Achievement motivation and introversion–extraversion are thought to have a curvilinear (inverted U) relationship to efficient performance; anxiety is said to have a facilitative effect on easy tasks and a debilitative effect on difficult tasks.

In this article we present an integrative theory that differs in several ways from the traditional personality–performance models of I/E, achievement motivation, and anxiety. In the traditional model,[2] some personality dimension (e.g., I/E) is thought to combine with a situational manipulation (e.g., placebo vs. caffeine) to produce a motivational state (e.g., arousal) that is, in turn, curvilinearly related to performance on a specific task (e.g., the verbal portion of the Graduate Record Examination). Thus, caffeine would be expected to facilitate the performance of extraverts but hinder that of introverts. This type of model has been used to explain the interactive effects on performance of various personality dimensions with various situational manipulations. However, rather than limit our analysis to one dimension of personality, one situational manipulation, or one performance task, we now integrate the seemingly diverse effects of different personality dimensions, a variety of situational manipulations, and a number of different cognitive performance tasks. Our approach also differs from the traditional one in that we go beyond the simple hypothesis that motivation is curvilinearly related to performance by specifying one component of information processing that is facilitated by increases in both arousal and effort, and another that is hindered by increases in arousal.

We summarize the interrelationships between personality, motivation, and performance in terms of a structural model (Figure 1). In this model, we show the effects of the personality constructs (impulsivity,[3] achievement motivation, and anxiety) in combination with situational moderators (e.g., time of day, caffeine, and success and failure feedback) on the motivational constructs of arousal and on-task effort. These motivational constructs are, in turn, shown as affecting the information-processing constructs of sustained-information transfer (SIT) and short-term memory (STM) resources. In keeping with conventional notation, we show observed variables as boxes and latent variables or hypothetical constructs as circles. We represent experimental manipulations as triangles and interactive effects as Xs. The solid lines in the figure represent monotonically positive effects; the dashed lines indicate monotonically negative effects. Although this model is expressed in terms of the causal effects of several latent variables (cf. Bentler, 1980), it is the result of a conceptual rather than an empirical analysis.

In justifying the model outlined in Figure 1, we first describe a general approach to hu-

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[1] The low reliability of Thematic Apperception Tests (TATs) makes it difficult to assess the relationship between achievement motivation and any other variable. (See, however, Atkinson, Bongort, & Price, 1977; Reuman, 1982.) Furthermore, although many studies report low correlations between anxiety and achievement motivation (see Atkinson, 1974; Atkinson & Birch, 1978) and between anxiety and either I/E or impulsivity (H. J. Eysenck, 1981), it is harder to find studies that measure both achievement motivation and I/E. We believe that this partly reflects the fragmented nature of the field and partly the separate domains of inquiry. See Revelle and Humphreys (1983) for a detailed discussion of the measurement issues associated with all three personality dimensions.

[2] To avoid appearing overly critical of the work of others, the specific example of a naive model we use is taken from Revelle, Amaral, and Turriff (1976); examples of slightly more complex models are from Craig, Humphreys, Rocklin, and Revelle, (1979), who used two dimensions of personality, and from Revelle, Humphreys, Simon, & Gilliland (1980), who used two situational manipulations (time of day and placebo/caffeine).

[3] Our original work in this area was concerned with evaluating H. J. Eysenck's theory of I/E. As we discuss later, recent studies have suggested that many of the arousal-based effects associated with I/E are actually due to the lower order factor of impulsivity. Thus, although we review the I/E literature, we prefer to develop our model in terms of impulsivity. See Revelle, Anderson, and Humphreys (in press) and Revelle and Humphreys (1983) for a more complete discussion of the experimental utility of separating the two lower order components of I/E.

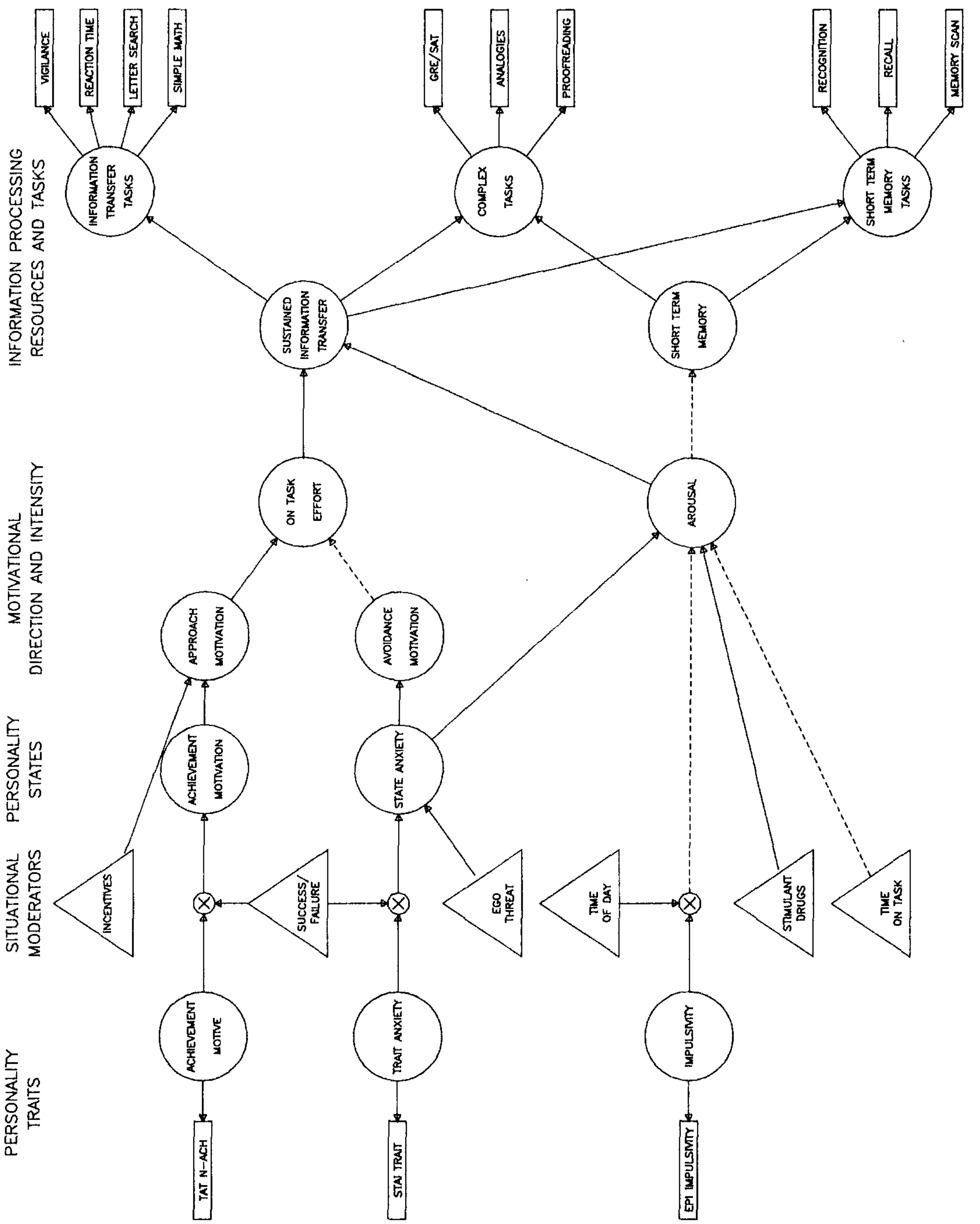

Figure 1. Conceptual structural model of the effects of personality, situational moderators, and motivational states on information processing and cognitive performance. (Solid lines represent positive influences, dashed lines represent negative influences, and the absence of a line indicates no direct influence. Circles represent latent variables, rectangles represent measureable variables, triangles represent experimental manipulations, and Xs show interactive effects.)

man information processing and show how the motivational constructs of effort and arousal can be incorporated into that approach. We then show how several different ways of manipulating effort and arousal have similar effects on SIT tasks and may have dissimilar effects on STM tasks. We then combine these motivational and information-processing constructs into a general model of the relationships between motivation and performance. Finally, we show how this general model can aid in the construction of specific theories linking these three personality dimensions (impulsivity, achievement motivation, and anxiety) to cognitive performance.

Definition of Terms

Before proceeding to develop and justify the specific assumptions in our structural model, it is useful to consider what is meant by some of the terms we are using. Note, however, that with our behavioral approach the constructs of effort and arousal are defined by their specification in the model rather than by self-report or physiological measurement. The definitions of the constructs offered in this section only serve to indicate the domain of phenomena in which we are interested.

Personality Traits

Personality traits are stable characteristics of individual differences that may be used to describe and to explain behavior (cf. Hirschberg, 1978). At the purely descriptive level, traits may represent mere counts of the frequency of certain behavioral acts (Buss & Craik, 1983). As such, traits are convenient summaries of consistent behaviors across different situations. In addition to such descriptive summaries, traits may also be used as explanations of behavior. In this latter case, traits reflect genetic, biological, temperamental, or learned bases for behavior. We do not wish, however, to make any distinction between temperamental traits, learned traits, or cognitive abilities. Rather we prefer to view traits as latent variables associated with the correlations between different behaviors. Such behaviors can be measured by self-reports, observations of others, or by objective test data (viz., Block & Block, 1979).[4]

The effect of these latent variables can only be estimated from the pattern of correlations (or covariances) within and between different behavioral domains. Correlations within domains are frequently referred to as reliabilities or internal consistencies, whereas correlations between domains are known as *convergent* and *discriminant* validities (Campbell & Fiske, 1956).

Personality States

Personality states are the result of the combination of traits and situations. Thus the trait of anxiety in combination with the threat of evaluation leads to the state of anxiety. Individuals with less trait anxiety are less likely to have high state anxiety in most situations than are individuals with more trait anxiety. Traits are predispositions to states. Differences in the amount of a particular trait only result in differences in state when the appropriate moderating stimuli are present. Thus, high trait anxiety results in high state anxiety only when appropriate eliciting cues are present. In the achievement-motivation literature, a similar distinction is made between *motive* and *motivation.* Individuals with a high motive to achieve (a trait) when faced with an achievement situation will have a higher level of achievement motivation (a state) than will individuals with a lower achievement motive.

Situational Moderators

Situational moderators are those characteristics of the situation that in combination

[4] It is beyond the scope of this article to consider in great detail the difference between traits as descriptions and traits as causes. One way to view this issue, however, is in analogy to the distinction between components and factors in psychometrics. Components are the weighted sums of observed variables and as such do not cause the variables, but are only convenient summaries. Factors, on the other hand, represent the unobservable common or shared variance of variables. Variables are seen as weighted sums of (hypothetical and unobservable) factors. Although factors can be used as explanations, components may only be used as summaries. Traits defined by the act frequency approach are analogous to components; traits used as casual explanations are analogous to latent factors. In a structural model, this distinction is captured by the direction of effects. Factors are presumed to be sources of variance in the observed variables; variables are sources of variance for components.

with personality traits, evoke particular personality states. Typical examples of such moderating variables include (but are not limited to) type of feedback (i.e., success or failure), monetary incentive, threat of punishment, time of day, stimulant drugs, depressant drugs, heat, cold, and noise.

Motivation

Motivation is a hypothetical construct that has traditionally been used to describe and explain differences in intensity and direction of behavior. It is the state that results from a combination of individual needs and desires with the stimulus properties of the situation. Although they are frequently combined under a single motivational construct, it is helpful to distinguish between the constructs of arousal and effort.

Arousal. Arousal is the state of the organism that in everyday terms means alertness, vigor, peppiness, and activation. Arousal may be thought of as a conceptual dimension ranging from extreme drowsiness at the one end to extreme excitement at the other. Arousal level is the result of internal and external stimulation. High levels of arousal are associated with high levels of sensory input; low levels of arousal are associated with low levels of sensory input. Specifically, loud noises, bright lights, time pressure, external distractors, and complex stimuli all lead to increases in arousal.

Indicants of arousal include both physiological and self-report measures. High arousal is characterized physiologically by higher levels of skin conductance, heart rate, breathing, metabolic activity, plasma levels of free fatty acid, and plasma levels of epinephrine and norepinephrine. Electrocortically, arousal is associated with alpha desynchronization and higher dominant frequencies. In terms of self-report, arousal is indicated by feeling more active, alert, and peppy and less sleepy or drowsy.

A distinction should be made here between *within*-subject and *between*-subject differences in arousal. Within individuals, increases in external stimulation are correlated with increases in the physiological measures just mentioned. Between subjects, however, the pattern is more complex. Individuals differ with respect to which physiological system responds the most to external stimulation. That is, some subjects respond to increases in noise with an increase in heart rate, whereas others respond with an increase in breathing rate. As an example, if one person increases his or her heart rate by 10 beats per minute but only increases his or her breathing rate by 1 breath per minute, whereas another person increases his or her heart rate by 1 beat per minute and his or her breathing rate by 5 breaths per minute, there seems to be a negative correlation between these two response systems. However, both people increased their breathing and heart rates in both systems; there was only a difference in relative change in the two systems. In this example, there was a positive correlation between the response in these two systems within individuals; between individuals there was a negative correlation.

It is partly this issue of within-versus-between individual measurement that has led to the response–specificity/generality argument between Lacey (1967) and Duffy (1962). However, as Lacey (1967) has made clear, even within subjects the picture is not as clear as one would like. Although normally linked, the various response systems can be shown to be independent of each other. He argued that "electrocortical arousal, autonomic arousal, and behavioral arousal may be considered to be *different forms* of arousal, each complex in itself" (p. 15). That is, they do covary, but they can be shown to be separate.

Although there are possibly many different arousal systems or physiological ways of becoming aroused,[5] it is the common behavioral

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[5] For example, stimulant drugs could have effects either presynaptically or postsynaptically but have similar effects on the overall rate of neurotransmission. More problematical for our theory is the fact that in free-running experiments, the sleep–wake cycle and the body-temperature cycle can be disassociated (Minors & Waterhouse, 1981). This finding indicates that temperature and sleep/wake are not responding to the same system albeit with different lags (Humphreys et al., 1980) but are in part responses to different systems. This result is a challenge to our theory only if different performance tasks adapt at different rates to shifts in these systems (e.g., shift-work or time-zone changes). At this time the evidence for differential adaption of performance tasks is quite tentative (Folkard & Monk, 1980; Hughes & Folkard, 1976; Monk, Knauth, Folkard, & Rutenfranz, 1978). Even if there were strong evidence for differential adaptation, this would not show that sleep/wake- and the body-temperature rhythms

effects with which we are concerned. We find it helpful to think of arousal as a *conceptual dimension* defined as that factor common to various indicants of alertness. We accept that there are specific factors associated with arousal manipulations, but feel that general arousal is theoretically parsimonious as a higher order construct. The usefulness of thinking of arousal as a single activational state is, however, an empirical question. We hope to show that conceiving of arousal as a general factor allows for a broad synthesis of research findings from a variety of personality and experimental paradigms.

It is also useful to distinguish between arousal at the macro and at the micro levels. At the micro level, arousal may be indexed by pupil dilation, changes in heart rate (both acceleration and deceleration), and changes in the electroencephalogram (EEG; Kahneman, 1973). But these measures do not index arousal at the macro level. At this more global level, arousal relates to the general feelings of alertness or activation (Thayer, 1967, 1978), body temperature (Blake, 1967), and hormonal excretions (Frankenhaeuser, 1975). It is also at this macro level that caffeine, time of day, and personality can be shown to affect performance (Revelle et al., 1980).

This distinction is partly one of duration. Arousal at the micro level has been associated with *pathway activation* (Posner, 1978), which is a consequence of such experimental manipulations as a warning signal for a reaction time test. The effects of such activation are very transitory and are indexed in milliseconds. Arousal at the macro level, however, is of much longer duration. The manipulations we consider to be at this level have effects that are indexed in minutes or in hours. An even broader level of analysis that might be related to the arousal concept is sometimes referred to as *stress* (Seyle, 1976). The effects of various stressors on an organism usually persist for days or for months. Although it is obvious that all three levels interrelate, our concern is at the macro level.

are different forms of arousal. The sleep–wake cycle is normally associated with the body-temperature cycle and with arousal. However, when these two rhythms are dissociated, it is possible that sleep/wake is more associated with variations in effort than it is with arousal (Minors & Waterhouse, 1981).

Effort. Effort is the motivational state commonly understood to mean trying hard or being involved in a task. Effort is increased when the subject tries harder, when there are incentives to perform well, or when the task is important or difficult. Effort can be applied to one task rather than another through experimental instructions or changes in the payoffs (rewards and punishments). A distinction needs to be made between the subjective feeling of trying hard and *on-task* effort, which we define later as the allocation of resources to the task at hand. Our theory is one of on-task effort rather than the subjective feeling of trying hard.

Arousal and effort are both hypothetical constructs. We think of these two constructs as separate and link them together under the rubric of motivation only to be consistent with previous usage. We acknowledge that experimental manipulations of one may affect the other and that many theorists have combined the two constructs. We believe, however, that it is useful to distinguish between the effects of stimulant drugs, time of day, and lack of sleep (arousal), and those of incentives, importance, difficulty, and instructions (effort). In some sense, this distinction is one between biological manipulations and cognitive ones. One of the major goals of this article is to provide a system whereby we can differentiate the constructs associated with these different sets of manipulations.

Motivation and Information Processing

Before proposing our specific theoretical ideas, we feel that it is worthwhile to consider in general terms (a) what a theory of the relationship between personality and performance should be and (b) why such a theory is needed. A theory about personality and performance should cover the entire range from individual differences and situational moderators to information-processing constructs and performance. Until now, theories of individual differences have been related to performance via ill-defined constructs. For example, a common assumption has been that performance is curvilinearly related to arousal. As such, this assumption is practically useless. It is merely a description of data, not an explanation. Furthermore, without a specification of the information-processing components involved, it is impossible to predict whether any given experimental task should show a curvilinear relationship with performance.

We believe that to make progress in this area, we need a theory that goes beyond the assumption of curvilinearity. Specifically, such a theory should get rid of the curvilinear assumption and replace it with two or more monotonic processes, at least one of which improves with increases in arousal and at least one of which deteriorates. These two processes, in combination, can produce curvilinearity. Models of this type have the advantage that they specify the tasks or kinds of tasks in which performance increments or decrements can be expected. Such a theory of two monotonic processes is also easier to test than is an assumption involving curvilinearity.

In keeping with Navon and Gopher (1979), we assume that the human information-processing system can be described as being composed of multiple allocatable resources:

> The human system is probably not a single-channel mechanism but rather a complicated system with many units, channels, and facilities. Each may have its own capacity (which is, roughly, the limit on the amount of information that can be stored, transmitted, or processed by the channel at a unit of time). Each specific capacity can be shared by several concurrent processes; thus it constitutes a distributable resource. (Navon & Gopher, 1979, p. 233)

There are two obvious ways to map motivational constructs into this general approach to information processing. The first is in terms of the concept of *allocation.* If a subject is performing two tasks simultaneously, we can plot performance on Task A as a function of performance on Task B. In general, across instructions and incentives designed to increase the importance of performing well on Task A, relative to the importance of performing well on Task B, there is a smooth trade-off between performance on the two tasks. That is, as performance on one task improves, performance on the other task tends to stay the same or to gradually decline. There are usually no abrupt changes in performance on either task. The conclusion that is drawn from such a performance-operating characteristic curve is that the subject is taking resources from one task and allocating them to the other task.

When only a single task is being performed, it is also possible to think about the allocation of resources. Basically there are three ways in which this could occur: (a) If the task has multiple components, the subject may allocate resources from one aspect of the task to another. For example, subjects may sacrifice accuracy in order to increase their speed (Pachella, 1974), or sacrifice the quality of their answers in order to increase the number of answers they produce (Bavelas & Lee, 1978). (b) Allocation of resources could also occur between an experimenter-defined task and a subject-defined task. Examples of a subject-defined task include worrying about performance, daydreaming, or attempting to do well on a task component that is not measured by the experimenter. Performance on the experimenter's task stays the same, or improves, as incentives to do well on it are increased and off-task incentives are decreased. Performance stays the same or gets worse as on-task incentives decrease and off-task incentives increase. (c) If there is a cost associated with the allocation of resources and if each additional unit of resource allocated to a task produces a decreasing amount of improvement in performance, there comes a point where the cost of adding resources equals the benefit gained by the improvement in performance (Navon & Gopher, 1979). Thus, it is also possible to think about resource allocation even when there is no detectable trade-off between task components and no detectable subject-defined task. That is, there may be resources that are not being used but that are not allocated unless the benefits for doing well on the task are increased.

A second way that motivation could be mapped onto this general information-processing model is in terms of the *availability* of resources. In keeping with Kahneman (1973), increases in motivation might actually create additional resources (make them more available), not just reallocate resources from one task to another or from a pool of unused resources to the experimenter-defined task. The process that is most compatible with traditional thinking about arousal (Kahneman, 1973) is simply that the total number of resources increases. It is also possible that an increase in arousal could lead to a decrease in the cost associated with allocating these resources. One way of thinking about this latter alternative is not that there is a reduction in the cost, but rather that the cost is deferred until a later time.

We should note that resource allocation and resource availability are metaphors and that there are many ways in which the functional distinction expressed by these metaphors can be preserved. They do, however, serve a purpose in communicating our hypothesis about a functional distinction between motivational constructs.

In trying to determine how many motivational constructs are needed to explain efficient performance, we start by assuming that effort manipulations affect the allocation of resources to on-task endeavors. By this we mean that the mechanism that is responsible for performance trade-offs in the dual-task situation is also responsible for some of the performance changes with effort manipulations in single-task situations. Our questions then are whether another motivational construct is required, and, if so, what the differences are in the relationships of the three personality dimensions and the two sets of motivational manipulations to the two constructs. Even though we realize that more than two motivational constructs may eventually be required, we wish to explore first the more parsimonious hypothesis that at most two are required. In the next section we specify some of the processes that get better and some of the processes that get worse with motivation. Once some of these have been specified, it is possible to specify the kind of results that would discriminate among alternative hypotheses about the number and the nature of motivational constructs.

Motivation and Performance Increments

In our search for processes that improve with arousal and effort, we have looked at performance changes in reaction time, letter cancellation, vigilance, and simple arithmetic tasks as a function of incentives, time of day, sleep deprivation, and the stimulant drugs amphetamine and caffeine (Revelle & Humphreys, 1983). The results are by no means entirely consistent, yet some firm conclusions can be drawn. Both an increase in incentives and an increase in arousal can improve speed and/or the number correct on these tasks without a compensating increase in the error rate.[6] Furthermore, there is almost no evidence that the stimulant drugs (caffeine and amphetamine) impair performance on these tasks (also see Gilbert, 1976; Weiss & Laties, 1962).[7]

The issue about whether overarousal deficits occur with noise and heat is not as clear. Poulton (1976) has reviewed the literature on the effects of heat, continuous noise, and intermittent noise on a variety of tasks. The studies he cited clearly show that these manipulations can improve letter cancellation, reaction time, vigilance, and simple arithmetic, but there are also many cases (Poulton, 1977) where these manipulations hurt these tasks. It is controversial, however, as to whether this debilitation is due to overarousal or to distraction, differential transfer, masking, and underarousal (Poulton, 1977, 1978, 1979). The issue is certainly not resolved (see Broadbent, 1978; Hartley, 1981; Poulton, 1981). Nevertheless, because Poulton has provided plausible explanations for at least some of the deleterious effects of noise and heat on these tasks and because comparable deficits do not occur with the stimulant drugs, we feel that it is worthwhile to explore a model of human performance that asserts that both arousal and effort

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[6] Many authors did not report error rates, so it was not always possible to tell if subjects were sacrificing accuracy in favor of speed. Still, enough studies reported error rates, or in the vigilance tasks reported *d'*s, to ensure that an absolute improvement in performance can occur.

[7] Hollingworth (1912) reported that small doses of caffeine hurt simple reaction time, whereas larger doses improved performance relative to a placebo. This result, however, is certainly not an overarousal effect as it was only the intermediate dose that hurt performance. As the author suggested, it may have been due to a change in criterion. Wenzel and Rutledge (1962) reported that small doses of caffeine (100 and 200 mg) improved complex visual reaction time relative to a placebo but that a 300-mg dose hurt performance. In the same study large doses of amphetamine did not similarly hurt performance, so this finding has to be viewed with some caution. Frowein (1981) has also reported that amphetamine hurt choice reaction time with an incompatible stimulus-response mapping, but not with a compatible mapping. This finding was not replicated in a subsequent study (as reported by Frowein, 1981) and must be considered tentative. The Wenzel and Rutledge (1962) study also involved a complex but not necessarily incompatible mapping, so it is possible that the effects of stimulant drugs on reaction time are moderated by stimulus-response compatability. It is interesting to note that incompatible stimulus-response mappings introduce an episodic-memory component into the task, so these effects may be examples of memory-induced arousal deficits.

manipulations increase the number of resources that are applied to these tasks.

We characterize these tasks (reaction time, vigilance, simple arithmetic, and letter cancellation) as information transfer (IT) tasks. By this we mean that the subject is required to process a stimulus, associate an arbitrary response (Posner, Snyder, & Davidson, 1980) to the stimulus, and execute the response. Furthermore, there is no appreciable retention of information required nor is there an appreciable amount of distraction. In addition, many of the tasks reviewed involve either temporal uncertainty or rapid pacing for an appreciable length of time. Indeed, a common observation was that the effects of arousal manipulations tended to show up only in the latter stages of an experimental session. Our conclusion, thus, is that both effort and arousal manipulations improve SIT.

Theoretical predictions. We assume that both an increase in on-task effort and an increase in arousal lead to an increase in the number of resources that are used to sustain IT. Furthermore, performance on vigilance, simple arithimetic, letter cancellation, and reaction time is assumed to be a monotonically increasing function of the number of resources applied. There is a point, however, where further increases in resources do not lead to increases in performance. In Norman and Bobrow's (1975) terminology, this point marks the data-limited region and performance is limited by the quality of the external data and the sensitivity of the subject. The region where performance does change with changes in resources is referred to as the resource-limited region. These empirical generalizations about improvements in SIT with increases in on-task effort and arousal along with the standard distinction between data and resource limitations permit us to understand some of the anomalies present in the motivational literature and to make some predictions.

The first issue to be considered concerns the extremely varied findings in this area. One investigator may report that stimulant drugs improve reaction time, whereas another observes no effect. Sometimes investigators report effects for some subjects but not for others. For example, Rapoport et al. (1981) reported that caffeine improves the performance of normal children and leaves the performance of adults unchanged. Many of these apparent inconsistencies are understandable given the idea that performance can be either resource limited or data limited. To illustrate, consider studies by Frowein (1981), and Sanders, Wijnes, and van Arkel (1982). Frowein (1981) reported that both amphetamine and visual degradation had significant effects on reaction time. Amphetamine reduced reaction time and visual degradation increased reaction time. There was no evidence, however, that these two variables interacted. In a basically similar study, Sanders et al. (1982) found that both sleep deprivation and visual degradation increased reaction time, but that these two variables also had interactive effects. That is, the effects of sleep deprivation were considerably greater with visually degraded stimuli than with visually nondegraded signals. Sanders (1983) has used this differential interaction pattern as evidence for the differential effects of these three variables on motivational states. He believes that the concept of arousal should be subdivided into two states (arousal and activation), with sleep deprivation affecting both states and amphetamine affecting only activation. Frowein's (1981) failure to find an interaction between amphetamine and stimulus degradation can be easily explained, however, by assuming that a normally rested subject is in the data-limited range with respect to performance with these visually degraded stimuli. This hypothesis can be tested if the initial arousal level of the subject can be lowered. Thus, we would predict that there would be an interaction between amphetamine and stimulus degradation for sleep-deprived subjects.[8]

[8] Sanders (1983) also recognized the importance of looking for an interaction between amphetamine and stimulus degradation on sleep-deprived subjects. His position, however, is that such an interaction would be evidence for an effect of amphetamine on what he calls *activation* as well as on what he and we refer to as *effort*. Our position, however, is that without evidence for differential effects of amphetamine and sleep deprivation on visually degraded signals, Sanders (1983) does not have sufficient evidence to distinguish between activation and arousal. That is, the entire distinction would rest on a failure to find an effect of barbituates on movement time (Frowein, 1981), as compared to finding effects of both sleep deprivation and amphetamine on movement time (Frowein, Reitsma, & Aquarius, 1981). There are several

Our generalization of this viewpoint is that stimulant drugs and other arousers are most likely to improve SIT performance when a task requires many resources, when the subjects are at a low level of arousal (early in the morning or when fatigued), or both. Tasks that require a large number of resources include but may not be limited to those with temporal uncertainty (Frowein et al., 1981; Sanders et al., 1982), degraded stimuli (Frowein, 1981; Sanders, et al., 1982), and spatial uncertainty (Sanders & Reitsma, 1982). In addition, as a subject acquires experience with a task, fewer resources are required.

When stimulant drugs improve the performance of children but leave the performance of adults relatively unchanged (Rapoport et al., 1981), a similar explanation applies. There are certainly many differences between children and adults. They may differ in their level of arousal, in how hard they try, and in the number of resources they have. The most compelling difference between children and adults, however, lies in their relative experience. Adults have acquired many skills that children do not yet have and can perform some tasks automatically that children must still perform under conscious control. The result is that on many of these tasks the adult requires fewer resources than the child does in order to do the task. Thus the adult is more likely to be in the data-limited range than is the child. This idea can be tested in two ways: The adults should be affected by the stimulant drugs (a) if the task was made more complex or (b) if their arousal level was lower.

Resource availability versus data limitations. One final issue needs to be addressed. If all of the tasks we have discussed utilize the same resources, then why aren't there substantial intertask correlations? To explain the low intercorrelations typically found between SIT tasks, it is useful to consider the implications of task-specific data limitations. In Figure 2 we show a family of hypothetical curves relating performance to the number of resources allocated to a task. Note that these curves differ in both the asymptotic level reached and the rate at which they approach the data-limited region. That is, some individuals are data limited at a higher level of performance than are others and some individuals approach the data-limited region faster (require the use of fewer resources) than do others. Both of these parameters presumably depend in a complex way on innate abilities (perceptual acuity, eye–hand coordination, etc.) and on experience (the strategies employed, the number of component skills automatized, etc.). The hypothesis that under particular conditions subjects will differ in terms of the number of resources they have available to sustain IT, does not address the question of whether they differ in their asymptotic levels or in their rate of approach to asymptotes. Thus we can see no basis for assuming that individuals who have a large number of resources (in a particular condition) have high asymptotes or require few resources to reach the data-limited range. Furthermore, there is no basis to assume that either asymptotic performance or the number of resources needed to reach asymptote on a vigilance task is positively correlated with asymptotic performance or the number of resources needed to reach asymptote on a simple arithmetic task. That is, the hypothesis that both vigilance and simple arithmetic depend on the availability of resources that can be used to sustain IT is not a hypothesis about the asymptotic level reached or about the number of resources required to reach asymptote.

It follows from these observations that when the rank ordering across subjects of number of resources available to sustain IT is substantially similar for two tasks, the rank orderings in terms of performance may not be very similar. In particular, the hypothesis that both tasks depend on common resources does not predict that performance will be positively correlated when performance is in the data-limited range. It is only when performance on the tasks is in the resource-limited range that the hypothesis predicts positive correlations. But even here individual differences in skills and abilities, other than those needed to sustain

reasons why we do not think this contrast is very compelling. First, it rests on a null result that needs to be replicated. Second, there are enough differences between the Frowein (1981) and the Frowein et al. (1981) studies (especially in the average movement times) to question the comparability of the results. Third, the effects of barbituates on performance are likely to be complex due to the known anti-anxiety effects (which should lead to an increase in effort and a decrease in arousal).

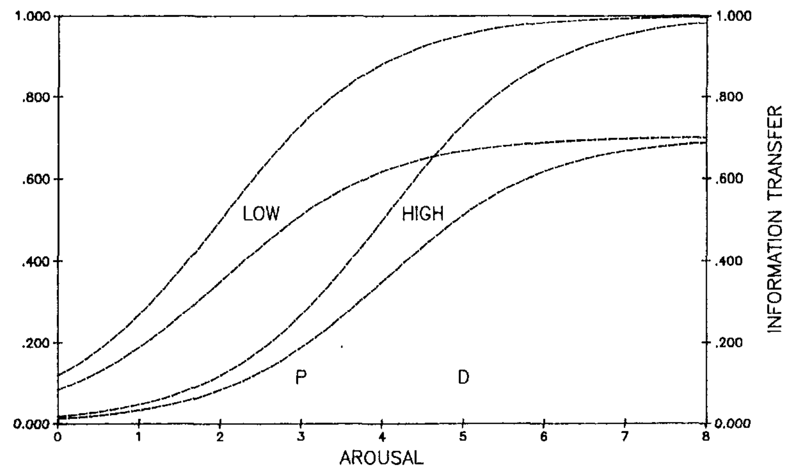

Figure 2. Presumed effects of arousal on information transfer. (Performance on tasks requiring vigilance and/or the rapid processing of information is helped by arousal. Such tasks may vary in the amount of arousal required to perform at any given level. The curves on the left represent tasks with lower IT demands than do the curves on the right. Points P and D represent the presumed level of arousal of subjects who were given a placebo or a stimulant drug. Individual differences in asymptotic level are shown to suggest differences in nonmotivational variables such as past training, skills, or ability.)

IT, attenuate the correlations. Thus our prediction is that correlations between sustained IT tasks will be higher when the tasks are in the resource-limited range than when they are in the data-limited range; tasks that respond to manipulations of arousal or effort should be more likely to intercorrelate than should those tasks that do not respond to such manipulations.

Motivation and Performance Decrements

There are of course a large number of ways to produce performance decrements that have nothing to do with motivation. We have already discussed how noise and heat might be distracting. In this section, however, we are concerned with performance decrements that are associated with the motivational constructs of arousal and effort. Given the information-processing approach that we have outlined, three conceptually distinct types of performance decrements can occur:

1. When two or more tasks are performed concurrently, performance on one task may suffer due to the allocation of resources to the other. This type of performance decrement may be further subdivided into those situations in which the experimenter defines both tasks and those in which the subject provides the second task. The experimenter-defined dual-task situations may be divided further into those situations where the subject is explicitly informed about both tasks, those complex tasks that require performance on two or more subtasks (with or without subject awareness of this implicit dual-task requirement), and the incidental-learning paradigms where the subject is not informed until the recall test about the dual-task requirements.

2. Prolonged exposure to states of high motivation might lead to a state of lowered motivation (fatigue, sleepiness, etc.). Thus, performance decrements that are observed after a long period of exposure to a motivating condition may result from lowered levels of motivation produced by the prolonged exposure.

3. It is possible that heightened motivation directly weakens some information-processing process or faculty. If a particular paradigm or set of paradigms is unusually sensitive to decrements with heightened motivation, some faculty or process common to these paradigms may be affected.

We should point out that it is possible to have decrements as a result of combinations of these types of situations. Thus, performance might deteriorate as a result of resource allocation (Type 1) and fatigue (Type 2), or resource allocation (Type 1) and the weakening of a particular resource (Type 3). In the following discussion, we briefly review each type of decrement.

Motivation and Dual-Task Performance

Easterbrook (1959) reviewed the literature on the effects of increased emotional arousal in dual-task situations. This, along with a subsequent review (Anderson, 1981), clearly indicates that under some conditions increases in motivation are accompanied by decreases in secondary-task performance. Performance on the primary task tends to stay the same or to show a slight improvement. These results are easily explained if under conditions of heightened motivation, subjects allocate more resources to the performance of the primary task. With SIT tasks in explicit dual-task situations, however, we have not found any evidence that clearcut arousal manipulations such as time of day, normal sleep as opposed to sleep deprivation, and stimulant drugs produce decrements in secondary-task performance (see Anderson, 1981). Our interpretation then is that performance decrements on secondary tasks result from changes in incentives that lead to changes in resource allocation. These changes in incentives may be obvious, as when payoffs are changed or instructions to do well on the primary or secondary task are used. There are also a variety of manipulations that probably change both the incentives for doing well and arousal levels (e.g., threat of shock, ego involving or threatening instructions).

It is also possible that the performance deficits that have been observed when subjects are performing a single task are due to the allocation or misallocation of resources. We have already mentioned that subjects can allocate resources to off-task endeavors, thoughts, and so forth. They may worry about what the experimenter is going to do to them, what is going to happen next period, whether to do their homework, what their friends are doing, and so forth.

Many performance decrements also have occurred with multicomponent tasks, and here a second explanation seems to be required. These multicomponent tasks can be conceived of as being composed of simpler tasks that must be performed simultaneously or in quick succession. In these circumstances it is possible that under conditions of high motivation the allocation of resources to different subtasks would be less than optimal. Decrements due to misallocation should depend greatly on the characteristics of the particular task, the instructions given the subject, and the experimental setting. Thus, decrements would be hard to replicate, and it might be difficult, if not impossible, to predict the circumstances under which an overarousal deficit would be observed.

Lowered Arousal Levels and Performance Decrements

Poulton (1979) has suggested that performance decrements due to the aftereffects of noise might be due to lowered levels of arousal. Similarly, Revelle et al. (1980) suggested that their low-impulsive subjects were fatigued in the evening because they had been more aroused for more of the day than had their high-impulsive subjects. Cohen (1980) has reviewed the literature concerning the aftereffects of anxiety-provoking situations, arousing situations, and situations where effort is expended. There may well be some differences between these various kinds of aftereffects, and not all of these may result in a state that can simply be characterized as being one of low arousal. At this time, however, the data simply do not permit us to make any finer distinctions.

Is Some Information-Processing Faculty Weakened by High Arousal?

The most likely candidates for processes or mechanisms weakened by high arousal are those that contribute to performance on STM tasks.[9] Folkard (1975), Hamilton, Hockey, and

[9] The only clear distinction between a STM task and the IT tasks that we have discussed is in the retention interval: Memory tasks require subjects to either maintain information in an available state through rehearsal or other processes or retrieve information that has not been attended to for a short period of time. Although it is true that recall immediately follows presentation of the last item in a memory-span task, there is a retention interval here as well because, as some of the items are rehearsed, attended to, or processed, other items are being ignored. We can not specify just how long a retention interval is required to unambigously qualify a task as a memory task. It may

Rejman (1977), and M. W. Eysenck, (1977) have suggested that high arousal hurts STM. We also have reviewed the effects of time of day, sleep deprivation, and stimulant drugs on tasks that require the retention of information for short periods of time (Humphreys, Lynch, Revelle, & Hall, 1983; Revelle & Humphreys, 1983). Performance on such tasks is generally hurt by higher levels of arousal (Blake, 1967; Folkard, Monk, Bradbury, & Rosenthal, 1977; Hamilton, Wilkinson, & Edwards, 1972). The only exceptions to this were the effects of stimulant drugs such as amphetamine and caffeine on digit span. In general, digit span seemed to have improved slightly or to have stayed the same when these drugs were used.

A recent study (Anderson & Revelle, 1983) conducted at Northwestern University, however, showed a clear detrimental effect of caffeine on a task that included a STM component. A memory-scanning task was used where subjects had memory sets of different sizes. There was a significant Set Size (two vs. six) × Drug (caffeine vs. placebo) interaction. That is, subjects were hurt by caffeine only with the set size of six. This task had previously been used in a study of adaptation to shift work (Folkard, Knauth, Monk, & Rutenfranz, 1976) where there had been a positive correlation between speed and body temperature for a set size of two but a negative correlation for a set size of six. Thus, the effect of caffeine on this task appears to be similar to that of circadian rhythms.

In another study, conducted at the University of Queensland, Humphreys used a running-memory-span task to provide the interference in a Brown–Peterson paradigm. Subjects were first shown four digits, one digit at a time. Then they were shown 0, 4, 8, or 16 consonants. Both digits and consonants were shown at a 750-ms rate and there was a 250-ms pause between each block of four stimuli. After 0, 4, 8, or 16 consonants had been presented, subjects were cued to recall digits or to recall the immediately preceding block of four consonants. Subjects were strongly encouraged to pay attention only to the current block of consonants. That is, they were instructed to stop rehearsing the digits as soon as the first consonant appeared and to stop rehearsing the previous block of consonants as soon as the first member of the next block appeared. In this study the most important comparison is between immediate consonant recall (collapsed over the number of prior consonants) and delayed digit recall (lags 8 and 16). These results are shown in Table 1. There was a significant Personality (high vs. low impulsive) × Drug (caffeine vs. placebo) × Recall Condition (immediate consonant vs. delayed digit) interaction, $F(1, 42) = 4.61$, $MS_e = 57.74$, $p < .05$. In the placebo condition the low impulsives did better on immediate consonant recall and worse on delayed digit recall than did the high impulsives. In the caffeine condition the low impulsives did better on delayed digit recall and worse on immediate consonant recall. The obvious conclusion is that there were trade-offs in terms of the number of resources allocated to the digit and consonant tasks. Whether caffeine was changing the relative importance of doing well on these two tasks or whether it interfered with some information-processing faculty so that subjects were forced to reallocate resources, remains to be answered. If they were being forced to reallocate, it could be due to difficulties they encountered with immediate consonant recall or with delayed digit recall.

A correlational analysis suggests, however, that the difficulty might have been with delayed digit recall (the retrieval of information from a less available state as opposed to maintaining information in an available state). In the placebo condition, a lag of 4 (digit recall) seemed

Table 1
Number of Consonants and Digits Recalled as a Function of Delay, Impulsivity, and Caffeine

	Immediate consonants		Delayed digits	
Group	Placebo	Caffeine	Placebo	Caffeine
Low impulsive	12.98	10.75	6.72	9.21
High impulsive	11.48	12.06	8.77	8.02

also be very important to distinguish between items that are recalled because they have been maintained in an available state and items that have to be retrieved from a less available state (Revelle & Humphreys, 1983; Wickens, Moody, & Dow, 1981). For the most part, however, the tasks that we have been concerned with involve both kinds of items in indeterminate amounts.

to act like a lag of 0. The correlation between the lag of 4 and the lag of 0 was .86 and the correlations between combined immediate consonant recall and recall at lags of 0, 4, 8, and 16 were .27, .48, −.03, and −.32, respectively. In the caffeine condition, a lag of 4 appeared to act like the longer lags. The correlation between the lag of 4 and the lag of 0 was .33, and the correlations between combined immediate consonant recall and lags 0, 4, 8, and 16 were .54, .10, −.13, and −.15, respectively.

Our overall conclusion then is that tasks that require the retention of information over short intervals (seconds to tens of seconds) are more likely than most tasks to show deficits associated with overarousal. We also found no evidence in our review that moderate incentives hurt performance on STM tasks (Geiselman, Woodward, & Beatty, 1982; Weiner, 1966). M. W. Eysenck (1980) has reported a study in which very large incentives hurt STM performance, but this deficit may have been due to the effects of these large incentives on anxiety. A very tempting inference from these results then is that some faculty or process associated with retention over short intervals is directly and adversely affected by high arousal, but not by high levels of effort. This conclusion, however, must remain tentative until the specific faculty or process is identified and until more work is done on the effects of achievement motivation and incentives on short-term memory.

THEORY OF THE RELATIONSHIP BETWEEN PERSONALITY, MOTIVATION, AND PERFORMANCE

The two motivational constructs of arousal and effort allow us to relate individual differences in personality to cognitive performance on a variety of tasks. In this section, before considering how the personality dimensions of impulsivity, anxiety, and achievement motivation relate to motivation and, subsequently, to performance, we first summarize our review of the motivation–performance literature. We then show how curvilinear relationships between motivation and performance can be decomposed into a positive relationship between arousal and sustained information transfer and a negative relationship between arousal and some function of short-term memory. We then consider how effort affects both of these components of information processing. Finally, we review how each of the three personality dimension relates to arousal and effort and suggest in turn how these three traits, in combination with situational moderators, affect cognitive performance.

Motivation, Sustained Information Transfer, and Short-Term Memory

Arousal and Sustained Information Transfer

Heightened arousal has a beneficial effect on performance of tasks that involve SIT. Furthermore, we have found very little evidence that there is any performance decrement on these tasks that is associated with overarousal per se. That is, the performance decrements that have been observed appear due either to specific effects of the arousal manipulation (e.g., distraction with noise) or to changes in incentives that result in the reallocation of resources from one task to another. We assume then that arousal monotonically increases the number of resources available to sustain IT. Furthermore, we assume that tasks that only involve SIT show monotonic improvements in performance with increases in the number of available resources.

Effort and Sustained Information Transfer

Cognitive manipulations such as payoffs and instructions can increase efficiency in vigilance and rapid decision-making tasks. These manipulations should result in the reallocation of resources from secondary tasks to primary tasks, from off-task thoughts to on-task endeavors and possibly from a pool of unused resources to on-task resources. In terms of our structural model, effort variables are assumed to affect SIT. As a final point, although we are asserting that increases in on-task effort and increases in arousal monotonically improve performance on SIT tasks, it is not necessarily the case that the process by which performance is increased is the same. In deriving our specific predictions, we do need to assume that the resources made available by arousal and those allocated to the experimental task because of increased on-task effort add together to drive the task toward the data-limited range.[10]

Arousal, Effort, and Short-Term Memory

We have shown that STM tasks are more likely than most tasks to show deficits with heightened arousal. Our assumption is that some resources that are involved in retention over these short intervals are reduced by heightened arousal, not that all such resources are reduced. Indeed it seems to us that many of the resources used in sustaining IT would also be helpful in STM paradigms (cf. Bowyer, Humphreys, & Revelle, 1983). Thus the ability to pay attention and to encode incoming stimuli might be enhanced, while at the same time the ability of a subject to maintain information in a readily available state through rehearsal or other processes (Baddeley & Hitch, 1974; Craik & Lockhart, 1972), or the ability to retrieve information that has not been maintained (Wickens, Moody, & Dow, 1981), might decrease. To provide for this possibility we have drawn arrows in Figure 1 indicating positive effects of SIT resources on STM tasks. Nevertheless, we are assuming that a mechanism or process involved in STM is monotonically decreased by increases in arousal but not by increases in effort.

Curvilinearity as Derived From Opposing Monotonic Processes

In this section we show how increasing SIT coupled with a decreasing memory component could combine to produce curvilinearity in multicomponent tasks. Consider the STM component that is present in many such tasks. Our assumption is that high arousal sometimes makes information that is necessary to perform the task unavailable after a period of only a few seconds. Furthermore, we assume that the probability that this occurs is a monotonically increasing function of arousal. As an example, consider a multiple-choice examination. After attending to and reading the question, the subject must remember it while attending to and reading the answers. Performance depends on whether the question is still available or can be retrieved when the correct answer is encountered. Obviously, the probability that the question will be remembered depends on many factors, including the length of the question, the particular material involved, and the time interval between reading the question and looking at the correct answer. In Figure 3 we show this hypothetical relationship between arousal and the probability that information that has been encoded will be remembered when needed. Two curves are shown that represent different memory requirements. Both curves start at 1.0 and decline to 0.0, with the curve for the more difficult memory requirements declining more rapidly.

For expositional purposes, all of the components of the task that require SIT are grouped together into one hypothetical SIT factor. Figure 2 shows what performance on this SIT factor as a function of arousal would be if we could somehow measure it in isolation. We have already grouped the memory components together in our memory construct. The relationship between this construct and arousal has been depicted in Figure 3. There is no a priori way to specify an appropriate combination rule for the SIT and STM factors in determining performance. However, for heuristic reasons we have used the product of

[10] To illustrate this point, consider the effects of amphetamine on simple reaction time. They are greater with variable foreperiods than with fixed foreperiods (Frowein et al., 1981; Trumbo & Gaillard, 1975), and it looks as if the main difference between variable and fixed foreperiods is in the extent to which the subject can prepare for the *go* signal (Niemi & Näätänen, 1981), Thus, subjects can be highly prepared with a fixed foreperiod in which they can anticipate the go signal, but because preparation is thought to be difficult if not adversive (Gottsdanker, 1975; Näätänen, 1972), a subject cannot maintain a state of high preparation throughout a variable foreperiod. If, for this task, we equate on-task effort with preparation (that is, if we assume that effort manipulations increase the amount of preparation and/or the number of occasions on which a subject is prepared), we can see how effort and arousal might interact. One possibility is that with high arousal, subjects can simply maintain a state of high preparation for a longer period of time. (Perhaps the cost of allocating resources is reduced or deferred.) Alternatively, high arousal might produce fast reaction times even when the subject is not highly prepared. The latter alternative receives some support from the interaction between stimulus intensity and fixed-versus-variable foreperiods (Niemi & Näätänen, 1981) as it is possible that high arousal makes weak go signals act like strong ones.

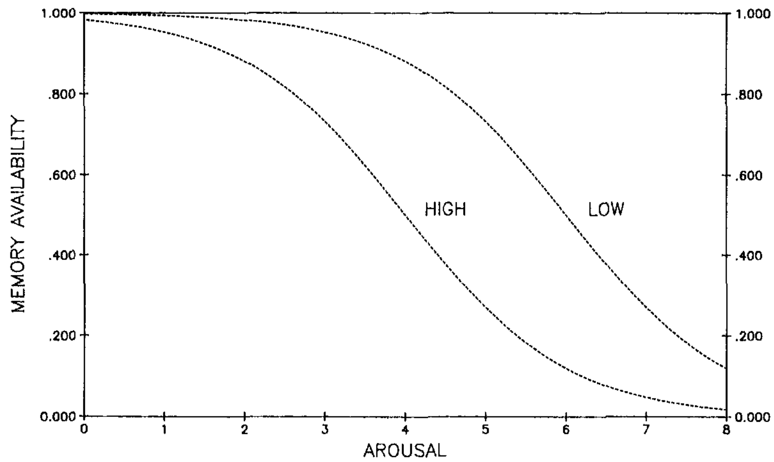

Figure 3. Presumed effects of arousal on short-term memory processes. (The probability of immediate retrieval is reduced by increases in arousal. Tasks may vary as to how sensitive the memory component is to arousal. The curve on the left represents a task that is more sensitive (has more memory demands) to arousal than does the curve on the right.)

the two components as an indicator of the relationship between performance on a multicomponent task and arousal. This relationship is given as the solid line in Figure 4. We can talk about tasks as being either *transmission limited* or *memory limited.* On the left side of the graph, performance is limited by the amount of resources needed to sustain IT. On the right side, performance is limited by the availability of some of the resources needed to remember information over short intervals.

The relationship between effort and performance is depicted in Figure 5. Increased effort is assumed to raise the SIT curve but not to decrease the memory curve. The lower of the two solid lines thus represents the relationship between performance and arousal with a low level of effort. The higher of the two solid lines represents this relationship for a higher level of effort. The result of the higher level of effort is to make it very difficult to show performance increments with increases

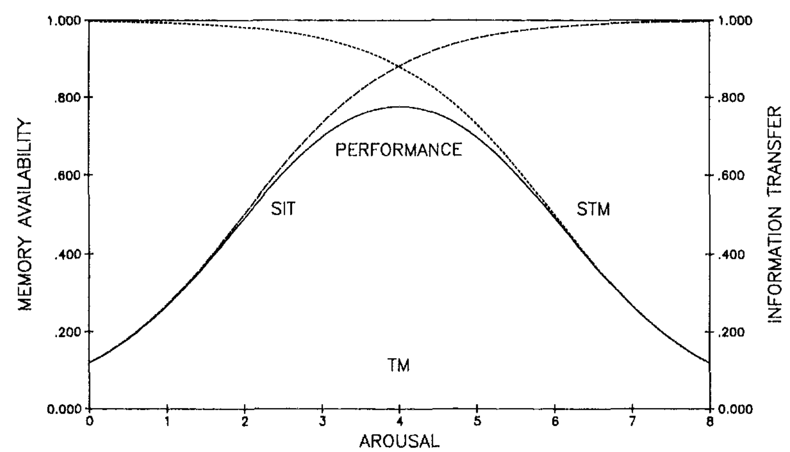

Figure 4. Curvilinearity derived from two opposing monotonic processes. (The ascending and descending curves represent the presumed effects of arousal on information transfer and memory, respectively. The solid curve represents the resultant relationship between arousal and complex performance. Performance to the left of point TM is said to be transmission limited; performance to the right of point TM is said to be memory limited.)

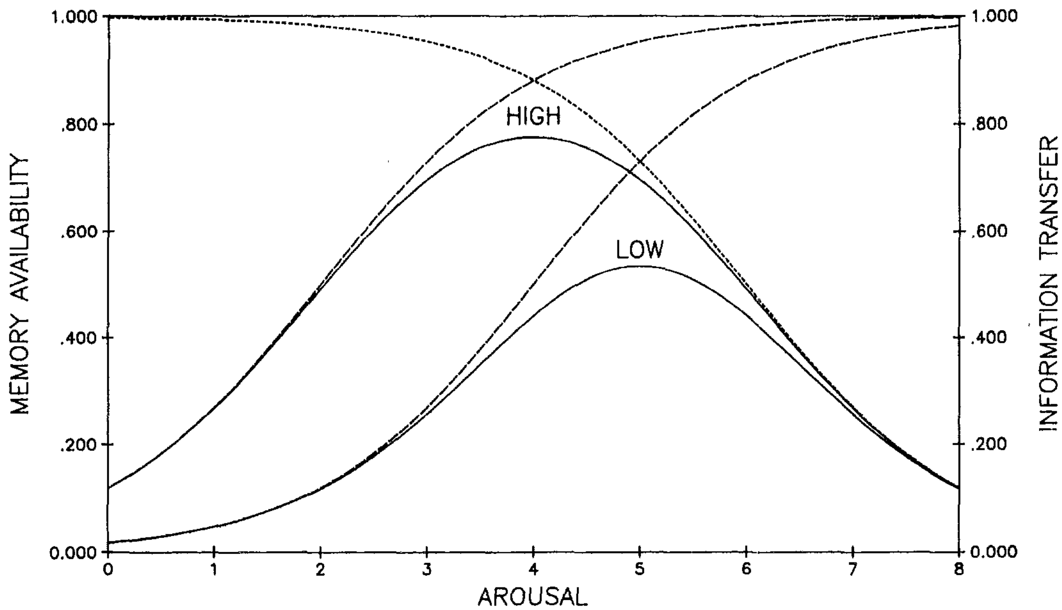

Figure 5. Curvilinearity derived from two opposing monotonic processes. (The effects of effort are to improve the information-transfer resource but not to affect the memory resource.)

in arousal. However, with high effort, peak performance and performance decrements both occur at lower arousal levels.

Summary of Motivation and Performance Relationships

We have shown how a general model that describes the effects of arousal and effort upon performance can account for three different relationships between arousal and performance: monotonically increasing, monotonically decreasing, and curvilinear (inverted U). We have suggested that on-task effort and arousal both increase (although perhaps in different ways) the resources allocated or available for SIT tasks. We also have suggested that arousal, but not effort, reduces the resources available for STM tasks. In the following section we show how important dimensions of individual differences may be related to the motivational constructs of arousal and effort and, subsequently, to performance.

Dimensions of Personality

In this section we briefly summarize the theoretical and empirical bases of each of three personality traits and then relate each of them to the motivational constructs of arousal and effort. We start first with introversion–extraversion, which we believe is related to arousal level; continue with achievement motivation, which may be related only to effort; and then conclude with a discussion of anxiety, which we believe is related to both arousal and effort.

Introversion–Extraversion and Arousal

Introversion–extraversion is one of the few personality dimensions that most personality theorists agree is robust enough to identify from study to study and investigator to investigator. The I/E dimension has been identified in behavioral measures (H. J. Eysenck, 1947), peer ratings, and self-report inventories (Cattell, 1957, 1973; Howarth, 1976; Norman, 1969). It has also been found to be a prominent factor in a set of items sampled from all of the major personality inventories (Browne & Howarth, 1977). It has been reported that differences in I/E are related to differences in physiological arousal, vigilance performance, social interaction, sexual behavior, creativity, effectiveness of cognitive processing, susceptibility to stress, and many other diverse experimental and observational findings (H. J. Eysenck, 1981; Lynn, 1981). Perhaps it is most important that individual differences in I/E have shown impressive stabilities across several decades (Conley, in press).

Compatible with all of these findings is H. J. Eysenck's (1967, 1976, 1981) suggestion that the chief difference between introverts and extraverts is a difference in basal arousal. That is, introverts are more aroused than extraverts. This hypothesis, in conjunction with the belief that arousal is curvilinearly related to performance (Hebb, 1955; Yerkes & Dodson, 1908), predicts that the performance of introverts and extraverts should be differentially affected by manipulations of arousal. Confirming evidence may be found in recent studies that have shown that the cognitive performance of introverts is hurt and that of extraverts is helped by stimulant drugs such as amphetamine (Gupta, 1977), and caffeine (Gilliland, 1980; Revelle et al., 1976; Revelle et al., 1980).

Introversion–Extraversion Versus Impulsivity

It is likely, although still somewhat controversial, that the impulsivity component of I/E is more related to individual differences in arousal than is the sociability component. Revelle et al. (1980) found that impulsivity had more systematic interactions with both time of day (which presumably is related to arousal differences in the diurnal rhythm) and caffeine than did either I/E by itself or the other chief component of I/E, sociability. Their findings were congruent with those that have shown that many of the results atributable to I/E are actually impulsivity effects (Amelang & Breit, 1983; Campbell, 1983; H. J. Eysenck & Levey, 1972; M. W. Eysenck & Folkard, 1980; Gray, 1972; Loo, 1979). This distinction between I/E and the lower order factor of impulsivity is important in that recent psychometric changes in the measurement of I/E (i.e., the Eysenck Personality Questionnaire, H. J. Eysenck & S. B. G. Eysenck, 1975) seem to have downplayed the importance of impulsivity (Claridge, 1981; Rocklin & Revelle, 1981), even as the experimental evidence for its importance has been accumulating.

In summary, the dimension of I/E, or at least the impulsivity component of this dimension, has been shown to interact consistently with a variety of arousal manipulations. Performance of high and of low impulsives differs as a function of both time of day and stimulant drugs. We conclude from this pattern of results that the impulsivity dimension is arousal related. More specifically, we assume that equal levels of external stimulation (e.g., noise, caffeine, time stress) lead to different levels of internal stimulation (arousal) for different people. That is, for the same dose of external stimulation in the morning, low impulsives are more aroused than are high impulsives.[11]

Impulsivity and Performance

To apply our motivation–performance model to the case of impulsivity, we do not need to assume that the arousal–performance curve differs for these two groups, but rather that the stimulation–arousal relationship leads to higher arousal for the low impulsives in the morning. Increases in stimulation lead to increases in arousal for both groups; similarly, decreases in stimulation or repetitive stimulation lead to decreases in arousal for both groups. Rather than present a single arousal–performance curve with the low impulsives

[11] An alternative assumption is associated with the concept of *transmarginal inhibition* (TMI), which suggests that high levels of stimuli evoke inhibitory processes and, as such, are actually de-arousing. This hypothesis that arousal is curvilinear with external stimulation and that introverts without stimulation are at their peak of internal arousal is consistent with the skin conductance data of Smith, Wilson, and Jones (1983). Smith et al. report that although introverts have a higher basal skin conductance with a placebo or low doses of caffeine than do extraverts, this difference disappears at high doses and extraverts have a slightly higher level of skin conductance. Unfortunately, they do not report their data in terms of impulsivity but rather use the Extraversion scale of the Eysenck Personality Inventory, which mixes these two primary factors to an unspecified amount.

Although it is probably the case that arousal does not increase at extreme levels of stimulation, we find TMI to be a poor explanation for our performance effects. Specifically, Anderson and Revelle (1982) found interactions of memory load, impulsivity, and caffeine on a proofreading task with a within-subjects design. As we have discussed in more detail (Revelle et al., in press), it is hard to see how the TMI hypothesis can account for improvements and decrements on tasks when memory load varies within subjects from item to item.

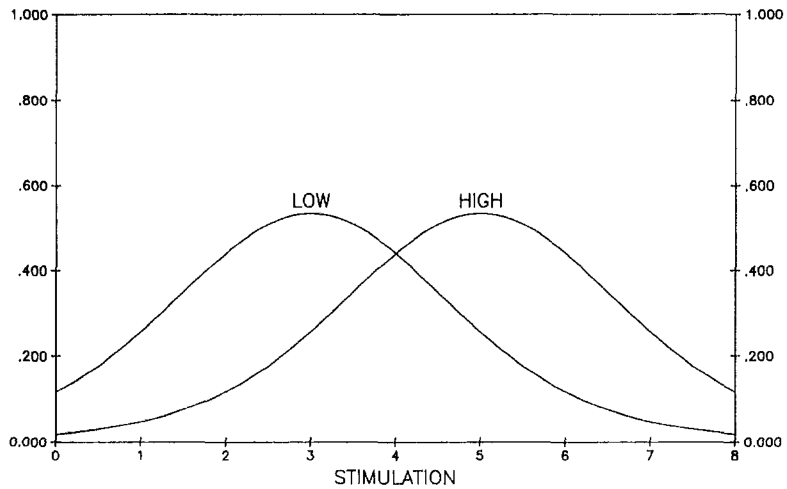

Figure 6. Impulsivity, arousal, and complex performance in the morning. (Low impulsives perform better at lower levels of stimulation than do high impulsives.)

farther to the right, we prefer to present two stimulation–performance curves, one for the low impulsives and one for the high impulsives. Thus, the classic Eysenckian theory appears in Figure 6.

At least in the morning, low impulsives are more aroused than are high impulsives. Thus, in the morning, low impulsives should have more resources for SIT and less of some STM resources. If we assume that the arousal level of the low impulsive is near the memory-limited range for complex tasks, then increases in arousal and the resultant decrease in some STM resources lead to a decrease in performance. For the high impulsive, on the other hand, performance is initially resource limited by the lack of SIT resources, and increases in arousal should lead to increases in performance (Figure 7). By evening, however, the low impulsives are now less aroused than are the high impulsives, and the effects of caffeine are reversed. Caffeine facilitates the performance of the low impulsives and hinders that of the high impulsives.

An interesting prediction that follows directly from the model, and one which we do not believe has been studied, is that effort should have a differential effect on high and on low impulsives. Low impulsives, normally being more aroused, are closer to the data-limited region of their SIT performance curve. High impulsives, on the other hand, because of their lower levels of arousal, are more able to benefit from effort manipulations that increase their number of SIT resources (refer ahead to Figure 7). This further suggests that low impulsives, whose behavior is not as affected by effort manipulations as that of the high impulsives, should not learn to be as responsive to social cues as high impulsives. This leads to the speculation that perhaps the relationship between impulsivity and sociability is this hypothesized greater responsivity of the high impulsive to incentive motivations in the morning.[12]

These predictions are in striking contrast to the dimension of achievement motivation, which (in our terminology) has never clearly been related to arousal but rather has been related to those situational conditions that affect effort.

[12] It is tempting to extend this speculation even further and to suggest that the primary characteristic of high impulsives is a rapid habituation to stimuli. Although the performance of high and low impulsives frequently does not differ early in a task, high impulsives seem unable to sustain their performance (cf. Bowyer et al., 1983). It is as if the arousal level of the high impulsive declines at a faster rate when in a repetitive environment than does that of the low impulsive. One of the findings of Revelle et al. (1980) was that the performance of the high impulsives was facilitated by caffeine in the evening of the second day in multiple-day studies. This could be explained by the decreased novelty (and subsequent de-arousal; cf. Gale, 1977) of the same experimental task given the previous day for the high impulsives.

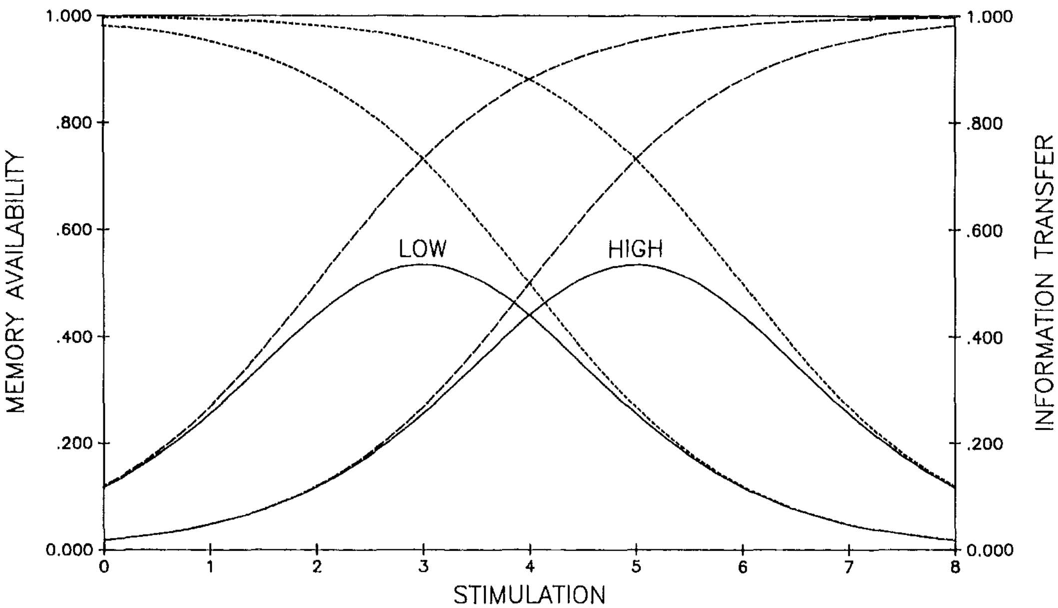

Figure 7. Impulsivity, arousal, and complex performance in the morning. (Low impulsives are in the memory-limited portion of the curve and experience decrements in performance with increases in arousal. High impulsives are in the transmission-limited portion of the curve and experience increments in performance with increases in arousal.)

Achievement Motivation and Effort

The study of achievement motivation is the study of the need

> to accomplish something difficult. To master, manipulate or organize physical objects, human beings, or ideas. To do this as rapidly, and as independently as possible. To overcome obstacles and attain a high standard. To excel one's self. To rival and surpass others. To increase self-regard by the successful exercise of talent. . . . [It is the study of how people] make intense, prolonged and repeated efforts to accomplish something difficult . . . [and] work with singleness of purpose towards a high and distant goal. To have the determination to win. To try to do everything well. To be stimulated to excel by the presence of others, to enjoy competition. To exert will power; to overcome boredom and fatigue. (Murray, 1938, p. 164)

Traditional Theories of Achievement Motivation

There are at least three basic approaches to the study of achievement motivation. The first is the broad societal theory of David McClelland (1961); the second is the formal theory of risk preference of John Atkinson (1957, 1964, 1974); and the third is the attributional formulation of Bernard Weiner (1972, 1978). Of these three approaches, the one that has been most often applied to the question of efficient cognitive performance is that of Atkinson and his associates (Atkinson & Birch, 1978; Atkinson & Raynor, 1974).

We recently reviewed these relationships between achievement motivation and performance (Revelle & Humphreys, 1983) and concluded that, although achievement motivation is difficult to measure, there are some consistent findings. Specifically, we found that the performance of high achievers is better than that of low achievers on tasks that are of moderate difficulty and that subjects believe are related to ability. Furthermore, the manipulations of achievement motivation are in striking contrast to the ones used in studies of impulsivity. That is, achievement motivation is affected by *telling* subjects that the task is important, is difficult, or is related to long-term goals. Because these manipulations seem very different from giving stimulant drugs or varying the time of day, we believe it is useful to think of achievement-motivation effects in terms of how hard subjects are trying to do a task (on-task effort) rather than in terms of how alert they are (arousal). We represent this in our model by a path from achievement motivation to on-task effort. A distinction should be made here between achievement motivation and approach motivation. We view achievement motivation as one source of approach motivation but recognize that other sources (e.g., incentives) exist.

An important question is whether there is a relationship between achievement motivation and arousal. Such a relationship is compatible with the intuitive feeling that engaging in a challenging task leads to an increase in alertness. In this case achievement motivation would be associated positively with approach motivation (and subsequently to on-task effort) as well as to arousal. Although we suspect that achievement motivation relates only to effort, we know of no experiments that allow us to reject the possibility of a path from achievement motivation to arousal. In the next section we derive the predicted consequences of both of these alternatives and specify the types of data that permit us to choose between them.[13]

Achievement Motivation and Performance

One of the advantages of our going beyond the simple assumption of a curvilinear relationship between motivation and performance is the ability to distinguish between alternative motivational models. For achievement motivation, the critical data involve tasks with a high memory load because both models predict that achievement motivation should be monotonically related to effort and thus to performance on SIT tasks.

Model 1: Achievement motivation affects only on-task effort. This is the simpler of the two models and equates achievement motivation with the directional rather than the intensity components of motivation.[14] What is particularly interesting about this case is that high levels of effort can increase the likelihood of an overmotivation effect, even though increases in effort per se do not lead to decreased performance. To understand this, we need to examine the effect of effort for subjects differing in arousal. Consider first an individual with a low level of arousal. Increases in effort should be monotonically related to the allocation of SIT resources to the experimenter-defined task, and performance on SIT tasks should improve until the data-limited range is achieved. If the task demands some STM, then it is possible that this individual will be memory limited before achieving the SIT asymptotic (data limited) level of performance. That is, even though the data-limited region has not been reached, further increases in resources for SIT do not improve performance because of the deficit in STM resources. Additional effort does not hinder performance; it is nugatory (Figure 8).

But now consider an individual with a high level of arousal. Once again increases in on-task effort should be monotonically related to the allocation of SIT resources to the experiment-defined task. Such a person, however, reaches the memory-limited region sooner and performs at a lower level than does the first individual. Furthermore, because of this STM limitation, performance is unaffected by a great range of variations in effort. Large increases in effort result in trivial increases in performance. Thus, even if achievement motivation only effects effort, if a highly motivated subject is challenged with an arousal manipulation such as public feedback or time pressure, and if the task has a STM component, the result is very likely to be a performance decrement. This prediction results, of course, in the type of finding reviewed by Atkinson (1974). In this model, high achievement motivation per se does not result in overmotivation, but it makes the subject very susceptible to arousal-induced deficits. This statement can be generalized to any manipulation

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[13] Yet another possibility to consider is a path from on-task effort to arousal. Many of the predictions of this model are the same as those of Model 2, with the exception that any increase of effort (e.g., through incentives) should reduce STM resources and lead to deficits on STM tasks. We have already reviewed the evidence against this path (Geiselman et al., 1982; Weiner, 1966) and do not consider it in more detail in this section.

[14] We differ here from Thomas (1983) who associates effort with intensity. We agree with him that persistence on a task can be used to index effort. We disagree, however, with his equating persistence with intensity. We prefer to think of time spent on a task as indicating the relative allocation of resources between different tasks but not the total availability of resources. In this context, much of the data supporting the theory of achievement motivation (Atkinson, 1974; Kuhl & Blankenship, 1979; Revelle & Michaels, 1976) show consistent effects for preferences between tasks or time spent on tasks. Efforts to show differences in intensity of performance (e.g., Rocklin, 1981) are much less successful.

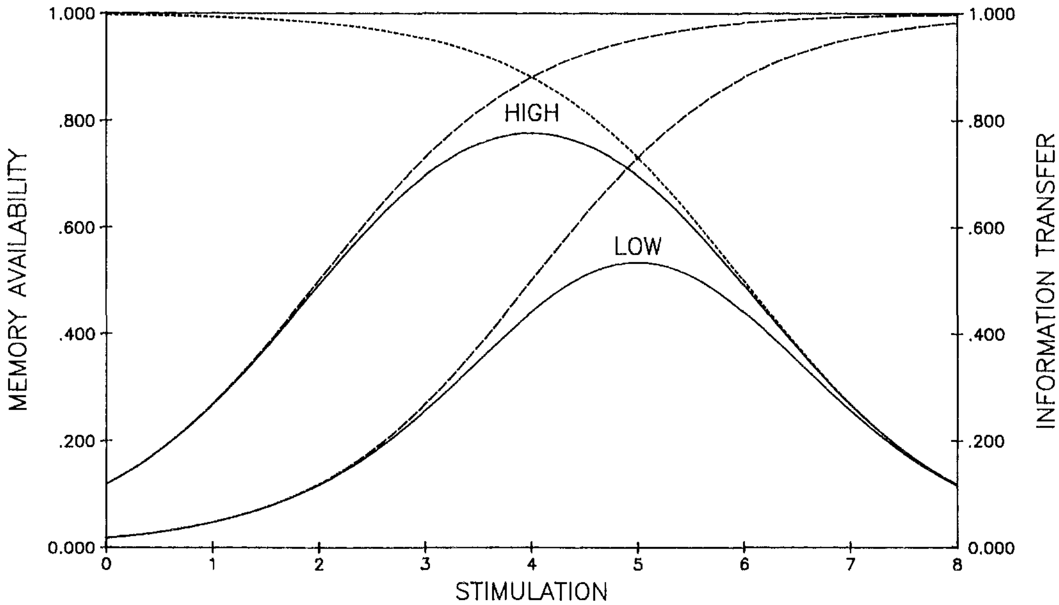

Figure 8. Achievement motivation, effort, arousal, and performance: Model 1. (The effects of arousal on subjects high and low in achievement motivation lead to decrements at lower levels of arousal for high-rather than for low-achievement-motivated subjects. Absolute performance of the high achievers always exceeds or equals that of the low achievers.)

of on-task effort. To us, high on-task effort does not lead to decrements in performance, but high on-task effort can not prevent arousal-induced (and memory-mediated) decrements in performance on tasks that require some STM.

What is particularly interesting is the pattern of results predicted by this model. Although high-achievement-motivated subjects exhibit decrements in their performance when they are also highly aroused, their performance should still be superior to that of less achievement-motivated subjects. That is, the peak of performance should occur at lower levels of arousal for high than for low achievers, but the absolute level of performance should never be less for the high achievers than for the otherwise-equivalent low achievers.

Model 2: Achievement motivation affects effort and arousal. Unlike Model 1, which predicts that the performance of high achievers is always superior to that of low achievers, Model 2 predicts that in an arousing situation, the performance of low achievers can exceed that of high achievers. This follows, of course, from the negative effects of arousal on STM resources. High achievers should have elevated SIT performance but depressed STM performance. In Model 1, on the other hand, higher achievers should have elevated SIT performance but equivalent STM performance. The predicted pattern of results for Model 2 are seen in Figure 9.

Both of these models of the effects of achievement motivation predict that high achievers should do better than low achievers when in a nonarousing situation or when performing a task that mainly requires SIT resources. They both predict that high achievers should achieve their optimal performance on complex tasks (those with some STM requirements) at lower levels of arousal than should low achievers. They make different predictions, however, for the case of performance in arousing situations. Model 1 predicts that the performance of high achievers is always superior to or equal to that of low achievers, whereas Model 2 suggests that the performance of high achievers should fall below that of low achievers. Given the data currently available, we can not choose between these two models. To distinguish them, it is necessary to show arousal-induced decrements in performance for subjects differing in achievement motivation.

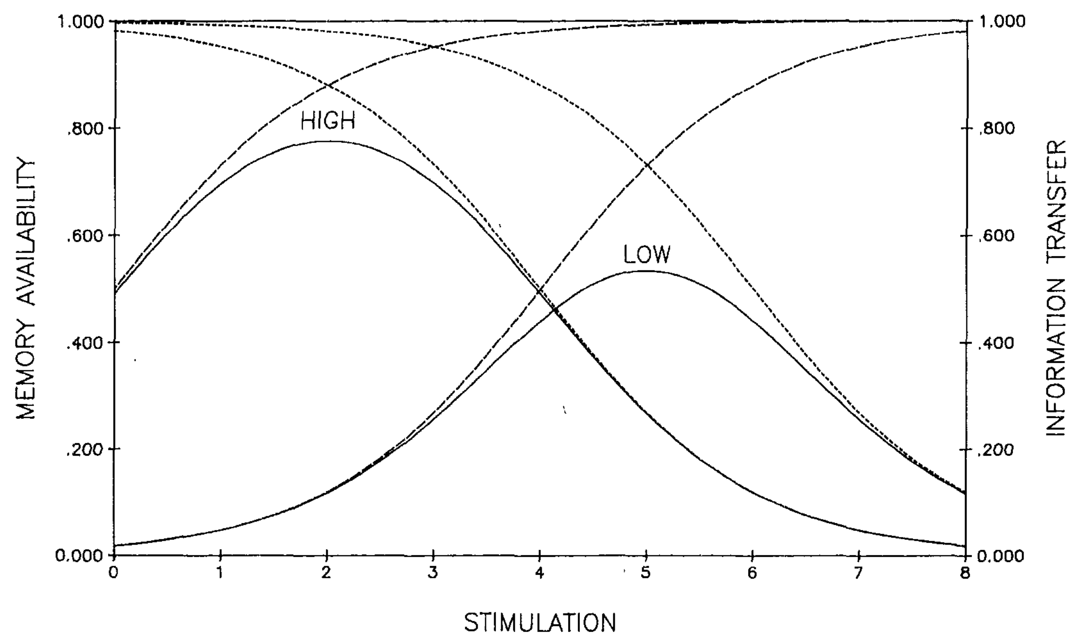

Figure 9. Achievement motivation, effort, arousal, and performance: Model 2. (The effects of arousal on subjects high and low in achievement motivation lead to decrements at lower levels of arousal for high- rather than for low-achievement-motivated subjects. At high levels of arousal, the performance of low achievers exceeds that of high achievers.)

Anxiety, Effort, and Arousal

Although achievment motivation and impulsivity seem to be related to different motivational constructs, effort and arousal, individual differences in anxiety have been shown to be related to both. Anxiety is one of the most commonly accepted causes of motivationally induced deficits in performance.[15] For many years, the arousal/drive theory of anxiety was predominant (Duffy, 1962; Spence & Spence, 1966). Recently, however, there has been a reinterpretation of anxiety in terms of cognitive attributions and the direction of attention (Mandler, 1975; Sarason, 1975; Weiner, 1972; Wine, 1971). Briefly, in this latter interpretation, anxiety is seen as a distractor. That is, anxious subjects devote cognitive capacity to worrying about their performance and thus have less capacity to devote to the task. A reconciliation of the drive and attributional theories can be found in the two-factor anxiety theories of Morris and Liebert (1970) and Schalling (1978). In those theories, some anxiety inductions are seen as affecting primarily somatic anxiety (arousal), others as affecting cognitive anxiety (reducing on task effort), and others as affecting both. It is interesting that this same dichotomy between effort and arousal may be seen in rats, where anxiety is thought to increase arousal but to lead to behavioral inhibition (Gray, 1982).

As we have shown in our recent review (Revelle & Humphreys, 1983), the effects of anxiety on cognitive performance depend on characteristics of the task and of the situation. Anxiety can either facilitate or hinder performance. High anxiety facilitates performance on easy tasks or when the feedback is positive. High anxiety hinders performance on difficult tasks or when the feedback is negative. There is some evidence that the relative contributions of the cognitive (worry) and somatic (arousal) components change as tasks continue.

[15] In the dimensional theory of H. J. Eysenck, anxiety loads very highly on the neuroticism dimension. Although we prefer to discuss the motivational effects of anxiety, certain studies only report results for neuroticism. Whenever this occurs, we assume that the results hold equally well for anxiety.

Anxiety and Avoidance Motivation

One way to capture this distinction between the arousal and the effort effects of anxiety is to introduce the concept of *avoidance motivation.* Just as we distinguish between achievement and approach motivation, so it is possible to separate anxiety from avoidance motivation. Increases in anxiety lead to increases in arousal as well as to increases in avoidance motivation. It is possible, however, to increase avoidance motivation without increasing either anxiety or arousal (particularly greasy plates increase the avoidance motivation for washing the dishes, but do not make most people anxious). Avoidance motivation, in turn, reduces on-task effort.

Anxiety and Performance

If we equate the worry or cognitive component of anxiety with avoidance motivation and a subsequent decrease in resources allocated to the task (which we define as a reduction in on-task effort), and if we allow the somatic tension (drive) aspects of anxiety to relate to arousal, then it is easy to see how anxiety should have a complex relationship to performance.

For SIT tasks with a low memory load, we make two predictions. If the worry component is in fact a transitory effect,[16] then early in the task, high anxiety should lead to low performance due to reduced on-task effort. This reduction in on-task effort is the consequence of too many off-task thoughts devoted to self-appraisal and negative self-statements. The additional arousal induced by anxiety should not improve SIT enough to compensate for this decrease in effort (Figure 10). As the avoidance component becomes less salient, the anxious subject should improve, first, doing as well as the less anxious subject (the negative effect of worry just canceling the positive effects of arousal) and, finally, doing better than the less anxious one (as the negative worries become progressively less important; Figure 11).

For tasks with a high memory load, however, we would expect that high anxiety would have the equivalent effect of any arouser and lead to decrements in performance. If the task is a complex learning task, then the anxious subject should be initially worse, but should become better as the task is restructured to reduce the memory load. If the task can be restructured enough to make the SIT component more important, then the high-anxious subject should finally do better than the low-anxious individual (e.g., Spence, Farber, & McFann, 1956).

In a complex task with a high memory load, success and failure feedback, by constantly instigating the worry component, should lead to performance decrements with failure feedback and increments with success feedback (e.g., Weiner & Schneider, 1971).

Evaluation of the Model

In deriving this model we have made some assumptions that are probably not testable. These include the assumptions that (a) resources are limited, (b) they can be shared between two or more tasks, (c) curvilinearity, when it occurs, can be derived from the opposing actions of two or more monotonic processes, and (d) trade-offs in dual task paradigms can serve as a model for some of the motivational effects in single-task paradigms.

From these assumptions, we have derived both a general model of the effects of motivation on performance and a specific model of how three personality traits relate to motivation and, subsequently, to performance. In the general model, we have proposed that at least two motivational constructs and two types of information-processing resources are required to explain the data that are available currently. In the specific model, we have suggested how individual differences in impulsivity, achievement motivation, and anxiety affect arousal, on-task effort, and cognitive performance.

The specific model is our interpretation of how the theories of I/E, achievement motivation, and anxiety may be related to each

[16] We use the dynamics of action model (Atkinson & Birch, 1970; see also Kuhl & Blankenship, 1979) to account for this transitory effect. If anxiety is seen as a source of "negaction" (*avoidance motivation* in our terms), then its inhibitory effect is negatively accelerated because of the cost of resisting the action. Achievement motivation, as an instigating force of the action tendency (approach motivation) on the other hand, instigates the resultant motivational tendency (on-task effort) until the task is initiated. In this model, the effects of inhibitory forces (anxiety) are most noticeable at the beginning of a session.

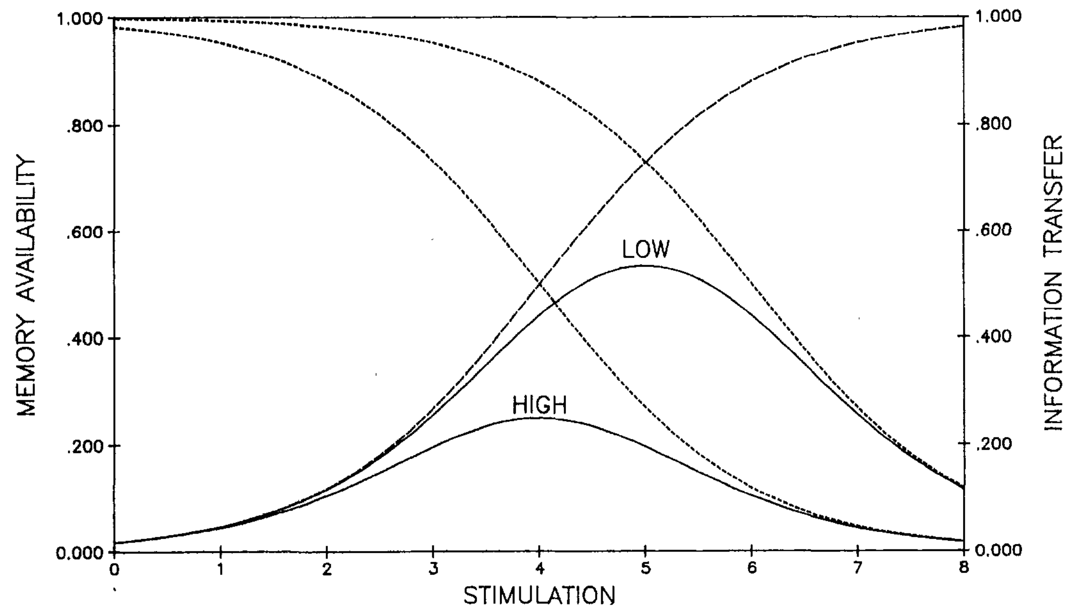

Figure 10. Anxiety and performance early in the task. (Anxiety is presumed to increase arousal but to decrease effort. This leads to a reduction in the memory resource and to a temporary reduction in the transmission resource.)

other, to motivation, and to performance. Alternative interpretations are possible. For example, it is possible that when compared to lower levels, high achievement motivation is associated with higher arousal as well as with greater effort. As we have pointed out already,

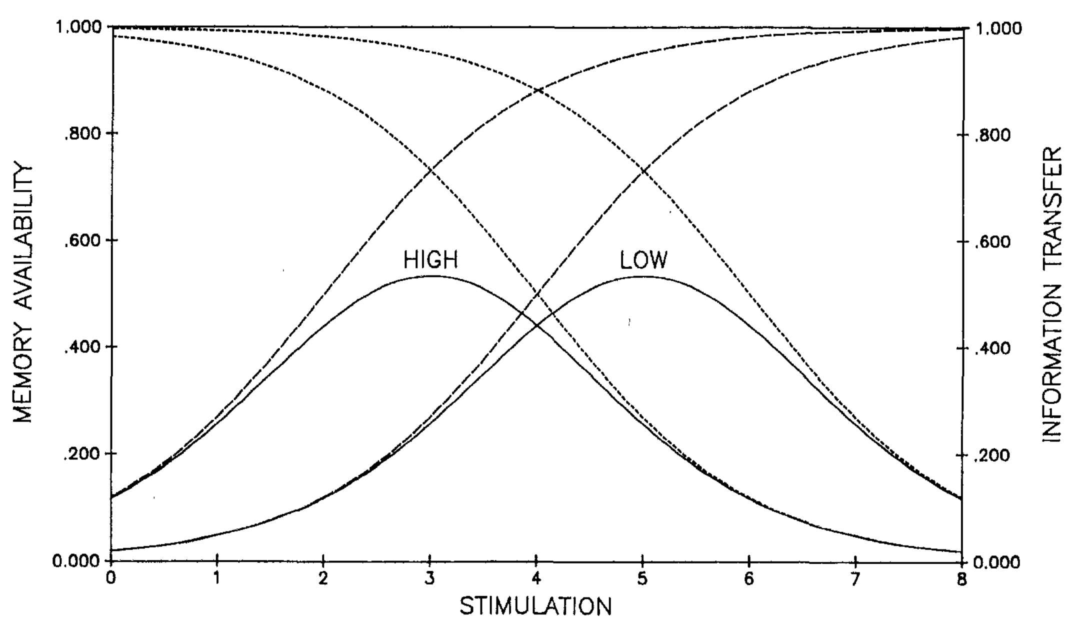

Figure 11. Anxiety and performance late in the task. (Anxiety is presumed to increase arousal but not to decrease effort. The information-transfer resource increases as the worry component of anxiety diminishes.)

these alternative specifications lead to slightly different predicted patterns of results and can be distinguished given appropriate data.

Operating at the general level, we have concluded that resource allocation (on-task effort) is not a sufficient explanation for all motivational effects and that the concept of resource availability (arousal) needs to be added. There are too many instances where performance improves with no detectable trade-offs and no indication that incentives for performing well have changed. We recognize that it is possible that for some situations and/or for some individuals, manipulations that increase effort also increase arousal (e.g., achievement motivation might be related to both effort and arousal). However, we believe that there are some manipulations that can change effort but not arousal. This represents the feeling that one can try hard without becoming aroused. For example, reading a difficult article requires a great deal of effort but is not normally thought of as arousing. Similarly, we believe that it is possible to change arousal without changing effort.

The best way to test this distinction is to identify the information-processing faculty that is hindered by arousal. We have suggested that arousal and not effort adversely affects some aspects of STM. The available data support this conjecture, but we still need direct comparisons of the effects of arousal and effort manipulations on performance in a variety of STM tasks. More generally, the effort/arousal distinction is testable if we assume that both effort and arousal increase SIT but that only arousal decreases an unspecified information-processing faculty. Then, given two levels of incentive ($I_2 > I_1$) and two levels of arousal ($A_2 > A_1$), the combination of I_2 and A_2 can produce worse performances than either I_2 and A_1 or I_1 and A_1, but it can not be worse than the combination of I_1 and A_2.

The next issue for the general model is whether more than one kind of arousal system is needed to account for behavior. Debate over this issue has been clouded by several misunderstandings. For one, physiological evidence can provide guidance as to where to look but can not answer this question. There has also been a failure to understand the implications of a resource model: specifically, how an increase in resources could lead to an improvement in one situation (a low initial arousal level, unskilled subjects, etc.) but not in another (a high initial arousal level, skilled subjects, etc.). The final misunderstanding concerns the concepts of shared and unique variance. For us, the behavioral construct of arousal is only properly applied when two or more manipulations can be shown to share variance; that is, when it can be shown that they have similar effects on performance. We expect that most if not all of the arousal manipulations also have unique variance components. Thus, a demonstration that sleep deprivation and impulsivity or noise and time of day have somewhat different effects on performance would not cause us to reject the unitary arousal hypothesis. A demonstration that there were two clusters of variables (e.g., noise and sleep deprivation vs. time of day and impulsivity) that had more in common within a cluster than between clusters would lead us to reject the assumption of a single arousal system.

Although difficult, it would be possible to test the adequacy of larger sections of the model as well as the overall model. To do this, we are required to specify each of the separate covariances between observables (e.g., measures of impulsivity, anxiety, and achievement motivation, vigilance performance, reaction time, and recall from memory) in terms of the hypothesized relationships between the observables and the latent variables (e.g., effort, arousal, SIT, and STM). As long as the model is specifiable and unique (i.e., has more estimates of parameters than parameters), we can obtain an overall goodness of fit of the model to the data. Such a fit can then be compared with the fit of specifications of other models, some with fewer and some with more paths to be estimated.

Before accepting or rejecting the entire model, it is useful to notice that the core of our model rests on two very simple, but powerful, assumptions. The first is, of course, that the effects of the different personality traits and of the many situational manipulations can be interpreted in terms of only two motivational states: effort and arousal. The second is that the interrelationships of many performance tasks can be expressed in terms of the amount of SIT and the amount of STM resources required by the separate tasks. We believe that, before the idea that there is any common thread to various motivational manipulations or any shared variance between various performance tasks is rejected, the power of a two-state–two-process model should be examined.

Our model may be thought of as a conceptual factor or components analysis rotated to experimental simple structure. That is, we believe that two dimensions of motivation can be used to summarize the interactive effects of situational moderators and personality traits. Although alternative rotations of these dimensions are possible, we believe that the use of effort and arousal as axes minimizes the number of nonzero relationships (paths) between the observed variables and the latent constructs. Similarly, our use of SIT and STM as axes of information processing is a conceptual simple structure of the resources required for cognitive tasks and, as such, is an idealized representation that emphasizes the independence of SIT and STM components. We recognize, however, that all cognitive tasks probably have some mixture of SIT and STM requirements, but in varying degrees. That is, we believe that it is possible to locate the resource requirements of vigilance, reaction time, analogies, and memory-scanning tasks in a two-dimensional space. Furthermore, experimental manipulation of the relative importance of SIT and STM components is possible within the same task. Thus, Leon and Revelle (1983), in a study of the effects of anxiety on analogical reasoning, varied the number of elements (SIT load) and transformations (STM load) in a set of geometric analogies (see also Mulholland, Pellegrino, & Glaser, 1980; Onken & Revelle, 1983). Similarly, the scanning task of Folkard et al. (1976; see also Anderson & Revelle, 1983) has alternate forms differing in STM load. The different forms of these tasks can be seen as occupying different locations in the resource space and should respond differently to motivational manipulations.

CONCLUDING REMARKS

We should acknowledge at this point that much of what we are proposing is not original. The idea that curvilinearity can be derived from opposing processes has been suggested by Easterbrook (1959) and others. More recently, Folkard (1975) and Hamilton et al. (1977) have identified attention, or its equivalent (see also Gale, 1977), and STM as processes that are differentially affected by arousal. Even more recently, Hockey (1979) and Humphreys et al. (1980) have discussed how these two separate processes can, when combined, produce curvilinearity. Our terminology and the analyses of dual-task situations are taken from Navon and Gopher (1979) and from Norman and Bobrow (1975). Our analysis of personality owes much of its inspiration to the work of Atkinson (1957, 1964, 1974) and H. J. Eysenck (1947, 1967, 1976, 1981). The relationship between anxiety and the direction of effort has been borrowed from Mandler (1975, 1979) and Sarason (1975) and Wine (1971). Finally, it should be obvious that our distinction between effort and arousal bears a marked resemblance to the incentive-versus-drive distinction of Hull (1952) and of Spence (1956) and to the two motivational states discussed by Broadbent (1971).[17]

We have not attempted to present a personality theory at the level of Atkinson (1974; Atkinson & Birch, 1978) or of H. J. Eysenck (1967, 1976, 1981). As an example, we do not have a theory of impulsivity but rather a description of its correlates. Instead, we have tried to present a framework in which a more adequate theory of achievement motivation, anxiety, and introversion–extraversion could be constructed. Likewise, we do not have a process theory of performance such as the one proposed by Sanders (1983). Our intention, however, has been to show how personality and motivational variables can be linked to a reasonably broad range of performance tasks. As a consequence, the information-processing constructs that we have proposed (SIT and STM) are necessarily more general than are those proposed by Sanders (1983). We feel that Sanders's approach complements ours and that his conclusions support our contention that a

[17] Part of the levels of control discussed by Broadbent (1971) can be included in this model if performance is seen to feedback through its effect on success and failure. Thus, effort can be seen as the higher order control process that responds to changes in performance demands by allocating resources. Similarly, arousal can be seen as the lower order control process that affects the availability of processing resources. Thomas (1983) also discusses the effects of feedback on subsequent effort.

limited number of motivational constructs can account for a substantial amount of the variance in the motivation–performance literature.[18]

What is different about our emphasis is that we not only try to show the interrelationships between these three personality dimensions, but our conception of a model is one in which multivariate and experimental psychology truly interact. We feel that the personality literature compels us to make a distinction between effort and arousal. It is then up to experimental psychology to find specific processes that are differentially affected by effort and arousal. Likewise, if we can discover just which aspect of memory is hurt by arousal and also can learn to measure this effect, then we would be forced to revise our ideas about impulsivity and arousal if high and low impulsives did not differ on this measure.

In this area of personality, motivation, and performance, we feel that it is necessary to consider, as we have done, a broad range of data at one time. The literature regarding the effects of motivation on performance is filled with failures to replicate and even with some occasional contradictions. If we had limited our review to one small area in this literature, there would have been few signs of consistency. It is only when a large portion of the area, including both the personality and the experimental literature, is reviewed that signs of consistency emerge.

The advantage of our multivariate approach is that by specifying a structural model we are able to compare our theory to others (i.e., to unifactorial motivational theories or to task-specific performance theories) as well as to relate new performance tasks and personality variables. We are claiming that the covariance structure of 3 personality dimensions, 6 situational manipulations, and 10 performance measures can be understood in terms of their relationships to the latent variables of effort, arousal, SIT, and STM. We do not claim that all of the variability in any single variable is accounted for by the model, but that the model provides a better fit to the shared variance of these tasks than does a single motivational or performance construct. Furthermore, we claim that there is indeed shared variance between performance tasks and that at least part of this shared variance can be accounted for by the constructs of SIT and STM. To the extent that this is true, we can then extend the theory beyond the data already collected (which were used to derive this theory) to other personality dimensions and performance tasks. If we are presented with a new performance measure, an analysis of that task in terms of the relative amounts of IT and STM demands allows us to predict how that task should respond to effort or to arousal manipulations. Similarly, by understanding how arousal and effort affect performance, we are able to predict how other manipulations (say alcohol or the minor tranquilizers) should affect tasks such as sustained monitoring.

We now can relate personality dimensions to situations and tasks and make specific predictions about the conditions under which people who differ in impulsivity, achievement motivation, or anxiety differ in their performance in a variety of situations. We make the following predictions, some of which are, as we have already noted, empirical generalizations, but most of which are only derivable from our model and the analyses we have presented:

1. Motivationally based correlations between SIT tasks can only be expected to be positive when performance is in the resource-limited range.

2. Arousal manipulations have larger positive effects on SIT tasks if the initial level of

[18] Nor do we suggest why arousal should facilitate information transfer or hinder short-term memory. A plausible model that is beyond the scope of this article could consider the effects of arousal as speeding up an internal clock or generally speeding up the flow of information through the system. Such an increased flow of information would lead to improvements in IT tasks but would have both facilitative and debilitative effects on memory tasks. STM tasks would be hindered by the increased interference associated with a higher rate of information flow. Memory for events learned under high arousal, however, could well show improvements due to what would be equivalent to more exposure to the to-be-learned material. Such a model can be understood most easily by considering arousal to reduce the psychological moment. A delay of 10 s of objective (external) time for a highly aroused subject would have the same effect as a longer delay (say 15 s) for a less aroused subject. Thus, in a STM task, the more aroused subject would be expected to have less recall after a fixed interval than would a less aroused subject. In a LTM study, however, the greater subjective time spent learning the material for the more aroused subject would more than compensate for the difference in recall interval.

arousal of the subjects is low or if the task requires more resources.

3. In the morning, high impulsives should experience a greater benefit on a SIT task from increases in arousal than should low impulsives.

4. High impulsives show greater improvements on SIT tasks with effort manipulations than do low impulsives.

5. After an initial delay, anxiety can improve performance on SIT tasks.

6. There is some aspect of STM that is directly and adversely affected by arousal but not by effort; thus, tasks that have a STM component are more likely to show overarousal deficits.

7. Low impulsives should be more likely to experience deficits on tasks with a STM load in the morning than are high impulsives.

8. There is a shift in the peak level of performance as a function of effort.

9. People who are high in achievement motivation are especially susceptible to arousal-induced performance decrements.

10. High-achievement-oriented subjects can show overmotivational deficits, but their performance should always be higher than the performance of low-achievement-oriented subjects in the same condition.

Finally, the utility of this approach should not be judged solely by the accuracy of our decision about specific details. We hope that this endeavor of linking personality to motivational states that in turn are linked to information processing accelerates the linking of the two paradigms of scientific psychology (Cronbach, 1957, 1975; H. J. Eysenck, 1966; Vale & Vale, 1969). The model should provide a common vocabulary and demonstrate to multivariate and experimental psychologists that they share some common questions. We also see a need for them to share their paradigms. We cannot begin to understand the relationship between effort and arousal if we limit ourselves to univariate experiments. Even when we look at two variables at once, it is frequently not possible to reject the hypothesis that the two variables have additive effects on some motivational state and that motivation is curvilinearly related to performance. A strategy that we would like to recommend is the inclusion of a third variable. The personality psychologist might want to look at the effects of two personality dimensions and of an effort or arousal manipulation. The experimental psychologist might prefer to look regularly at one personality dimension (impulsivity or achievement motivation) along with two experimental manipulations. Of course, this is no panacea, for, in addition to the conceptual problems of just what is the correct linkage between these personality constructs and motivational states, there are some serious measurement problems associated with these personality constructs. However, such a strategy would permit multivariate and experimental psychologists to make progress together.

References

Amelang, M., & Breit, C. (1983). Extraversion and rapid tapping: Reactive inhibition or general cortical activation as determinants of performance differences. *Personality & Individual Differences, 4,* 103–105.

Anderson, K. J. (1981). *The current status of the Easterbrook hypothesis.* Unpublished manuscript, Northwestern University.

Anderson, K. J., & Revelle, W. (1982). Impulsivity, caffeine, and proofreading: A test of the Easterbrook hypothesis. *Journal of Experimental Psychology: Human Perception and Performance, 8,* 614–624.

Anderson, K. J., & Revelle, W. (1983). The interactive effects of caffeine, impulsivity, and task demands on a visual search task. *Personality and Individual Differences, 4,* 127–134.

Atkinson, J. W. (1957). Motivational determinants of risk-taking behavior. *Psychological Review, 64,* 359–372.

Atkinson, J. W. (1964). *An introduction to motivation.* New York: D. Van Nostrand.

Atkinson, J. W. (1974). Strength of motivation and efficiency of performance. In J. W. Atkinson & J. O. Raynor (Eds.), *Motivation and achievement.* (pp. 117–142). Washington, DC: V. H. Winston.

Atkinson, J. W., & Birch, D. (1970). *The dynamics of action.* New York: Wiley.

Atkinson, J. W., & Birch, D. (1978). *Introduction to motivation.* New York: D. Van Nostrand.

Atkinson, J. W., Bongort, K., & Price, L. H. (1977). Explorations using computer simulation to comprehend thematic apperceptive measurement of motivation. *Motivation and Emotion, 1,* 1–27.

Atkinson, J. W., & Raynor, J. O. (Eds.). (1974). *Motivation and achievement.* Washington, DC: V. H. Winston.

Baddeley, A. D., & Hitch, G. J. (1974). Working memory. In G. H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 8, pp. 47–89). New York: Academic Press.

Bavelas, J., & Lee, E. S. (1978). Effects of goal level on performance: A trade-off of quantity and quality. *Canadian Journal of Psychology, 32,* 219–240.

Bentler, P. M. (1980). Multivariate analysis with latent variables: Causal modeling. *Annual Review of Psychology, 31,* 419–456.

Blake, M. J. F. (1967). Time of day effects on performance in a range of tasks. *Psychonomic Science, 9,* 349–350.

Block, J. H., & Block, J. (1979). The role of ego-control and ego-resiliency in the organization of behavior. In W. A. Collins (Ed.), *Minnesota Symposium on Child Psychology* (Vol. 13). Hillsdale, NJ: Erlbaum.

Bowyer, P., Humphreys, M. S., & Revelle, W. (1983). Arousal and recognition memory: The effects of impulsivity, caffeine, and time on task. *Personality and Individual Differences, 4,* 41–49.

Broadbent, D. E. (1971). *Decision and stress.* London: Academic Press.

Broadbent, D. E. (1978). The current state of noise research: A reply to Poulton. *Psychological Bulletin, 85,* 1052–1067.

Browne, J. A., & Howarth, E. (1977). A comprehensive factor analysis of personality questionnaire items: A test of twenty putative factor hypotheses. *Multivariate Behavioral Research, 12,* 399–427.

Buss, D. M., & Craik, K. H. (1983). The act frequency approach to personality. *Psychological Review, 90,* 105–126.

Campbell, D. T., & Fiske, D. W. (1956). Convergent and discriminant validation by the multitrait–multimethod matrix. *Psychological Bulletin, 56,* 81–105.

Campbell, J. B. (1983). Differential relationships of extraversion, impulsivity, and sociability to study habits. *Journal of Research in Personality, 17,* 308–314.

Cattell, R. B. (1957). *Personality and motivation: Structure and measurement.* Yonkers-on-Hudson, NY: World Book.

Cattell, R. B. (1973). *Personality and mood by questionnaire.* San Francisco: Jossey-Bass.

Claridge, G. (1981). Psychoticism as a dimension of personality. In R. Lynn (Ed.), *Dimensions of personality.* Oxford, England: Pergamon Press.

Cohen, S. (1980). Aftereffects of stress on human performance and social behavior: A review of research and theory. *Psychological Bulletin 88,* 82–108.

Conley, J. J. (in press). The hierarchy of consistency: A review and model of longitudinal findings on adult individual differences in intelligence, personality, and self opinion. *Personality and Individual Differences.*

Craik, F. I. M., & Lockart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior, 11,* 671–684.

Craig, M. J., Humphreys, M. S., Rocklin, T. R., & Revelle, W. (1979). Impulsivity, neuroticism, and caffeine: Do they have additive effects on arousal? *Journal of Research in Personality, 13,* 404–419.

Cronbach, L. J. (1957). The two disciplines of scientific psychology. *American Psychologist, 12,* 671–684.

Cronbach, L. J. (1975). Beyond the two disciplines of scientific psychology. *American Psychologist, 30,* 116–128.

Duffy, E. (1962). *Activation and behavior.* New York: Wiley.

Easterbrook, J. A. (1959). The effect of emotion on cue utilization and the organization of behavior. *Psychological Review, 66,* 183–201.

Eysenck, H. J. (1947). *Dimensions of personality.* New York: Praeger.

Eysenck, H. J. (1966). Personality and experimental psychology. *Bulletin of the British Psychological Society, 19,* 1–28.

Eysenck, H. J. (1967). *The biological basis of personality.* Springfield, IL: Charles C Thomas.

Eysenck, H. J. (Ed.). (1976). *The measurement of personality.* Baltimore: University Park Press.

Eysenck, H. J. (Ed.). (1981). *A model for personality.* New York: Springer-Verlag.

Eysenck, H. J., & Eysenck, S. B. G. (1975). *Manual for the Eysenck Personality Questionnaire.* San Diego, CA: Educational and Industrial Testing Service.

Eysenck, H. J., & Levey, A. (1972). Conditioning, introversion-extraversion and the strength of the nervous system. In V. D. Nebylitsyn & J. A. Gray (Eds.), *Biological bases of individual behavior* (pp. 206–220). New York: Academic Press.

Eysenck, M. W. (1977). *Human memory.* Oxford, England: Pergamon Press.

Eysenck, M. W. (1980, November). *Effects of incentives on working memory.* Paper presented at the meeting of the Psychonomic Society, St. Louis, MO.

Eysenck, M. W., & Folkard, S. (1980). Personality, time of day, and caffeine: Some theoretical and conceptual problems in Revelle et al. *Journal of Experimental Psychology: General, 109,* 32–41.

Folkard, S. (1975). Diurnal variation in logical reasoning. *British Journal of Psychology, 66,* 1–8.

Folkard, S., Knauth, P., Monk, T. H., & Rutenfranz, J. (1976). The effect of memory load on the circadian variation in performance efficiency under a rapidly rotating shift system. *Ergonomics, 19,* 479–488.

Folkard, S., & Monk, T. H. (1980). Circadian rhythms in human memory. *British Journal of Psychology, 71,* 295–307.

Folkard, S., Monk, T. H., Bradbury, R., & Rosenthal, J. (1977). Time of day effects in school children's immediate and delayed recall of meaningful material. *British Journal of Psychology, 58,* 45–50.

Frankenhaeuser, M. (1975). Experimental approaches to the study of catecholamines and emotion. In L. Levi (Eds.), *Emotions: Their parameters and measurement* (pp. 209–234). New York: Raven.

Frowein, H. W. (1981). Selective effects of barbituate and amphetamines on information processing and response execution. *Acta Psychologica, 47,* 105–115.

Frowein, H. W., Reitsma, D., & Aquarius, C. (1981). Effects of two counteracting stresses on the reaction process. In A. D. Baddeley & J. Long (Eds.), *Attention and performance IX* (pp. 575–589). Hillsdale, NJ: Erlbaum.

Gale, A. (1977). Some EEG correlates of sustained attention. In R. R. Mackie (Ed.), *Vigilance.* New York: Plenum Press.

Geiselman, R. E., Woodward, A. E., & Beatty, J. (1982). Individual differences in verbal memory performance: A test of alternative information-processing models. *Journal of Experimental Psychology: General, 111,* 109–134.

Gilbert, R. M. (1976). Caffeine as a drug of abuse. In R. G. Gibbins, Y. Israel, H. Kalant, R. E. Popham, W. Schmit, & R. G. Smart (Eds.), *Research advances in alcohol and drug problems* (Vol. 3, pp. 47–176). New York: Wiley.

Gilliland, K. (1980). The interactive effect of introversion-extraversion with caffeine-induced arousal on verbal performance. *Journal of Research in Personality, 14,* 482–492.

Gottsdanker, R. (1975). The attaining and maintaining of preparation. In P. Rabbit & S. Dornic (Eds.), *Attention and performance V* (pp. 33–49). London: Academic Press.

Gray, J. A. (1972). The psychophysiological nature of introversion-extraversion: A modification of Eysenck's theory. In V. D. Nebylitsyn & J. A. Gray (Eds.), *Biological bases of individual behavior* (pp. 182–205). New York: Academic Press.

Gray, J. A. (1982). *Neuropsychological theory of anxiety: An investigation of the septal-hippocampal system.* Cambridge, England: Cambridge University Press.

Gupta, B. S. (1977). Dextroamphetamine and measures of intelligence. *Intelligence, 1,* 274–280.

Hamilton, P., Hockey, R., & Rejman, M. (1977). The place of the concept of activation in human information processing theory: An integrative approach. In S. Dornic (Ed.), *Attention and performance VI* (pp. 463–486). London: Academic Press.

Hamilton, P., Wilkinson, R. T., & Edwards, R. S. (1972). A study of four days partial sleep deprivation. In W. P. Colquhoun (Ed.), *Aspects of human effeciency: Diurnal rhythms and loss of sleep* (pp. 101–113). London: English University Press.

Hartley, L. R. (1981). Noise does not impair by masking: A reply to Poulton's "Composite model for human performance in continuous noise." *Psychological Review, 88,* 86–89.

Hebb, D. O. (1955). Drives and the C.N.S. (conceptual nervous system). *Psychological Review, 62,* 243–254.

Hirschberg, N. (1978). A correct treatment of traits. H. London (Ed.), *Metatheories of personality* (pp. 45–67). New York: Wiley.

Hockey, R. (1979). Stress and the cognitive components of skilled performance. In V. Hamilton & D. M. Warburton (Eds.), *Human stress and cognition* (pp. 141–177). London: Wiley.

Hollingworth, H. L. (1912). The influence of caffeine on mental and motor efficiency. *Archives of Psychology, 22,* 1–166.

Howarth, E. (1976). Were Cattell's "personality sphere" factors correctly identified in the first instance? *British Journal of Psychology, 67,* 213–230.

Hughes, D. G., & Folkard, S. (1976). Adaptation to an 8-h shift in living routine by members of a socially isolated community. *Nature, 264,* 432–434.

Hull, C. L. (1952). *A behavior system.* New Haven, CT: Yale University Press.

Humphreys, M. S., Lynch, M. J., Revelle, W., & Hall, J. W. (1983). Individual differences in short-term memory. In R. Dillon & R. Schmeck (Eds.), *Individual differences in cognition* (pp. 35–64). New York: Academic Press.

Humphreys, M. S., Revelle, W., Simon, L., & Gilliland, K. (1980). Individual differences in diurnal rhythms and multiple activation states: A reply to M. W. Eysenck and Folkard. *Journal of Experimental Psychology: General, 109,* 42–48.

Kahneman, D. (1973). *Attention and effort.* Englewood Cliffs, NJ: Prentice-Hall.

Kuhl, J., & Blankenship, V. (1979). The dynamic theory of achievement motivation: From episodic to dynamic thinking. *Psychological Review, 85,* 239–248.

Lacey, J. L. (1967). Somatic response patterning and stress: Some revisions of activation thory. In M. H. Appley & R. Trumbell (Eds.), *Psychological stress* (pp. 14–37). New York: Appleton-Century-Crofts.

Leon, M. R., & Revelle, W. (1983). *The effects of anxiety on analogical reasoning: A test of three theoretical models.* Manuscript submitted for publication.

Lynn, R. (Ed.). (1981). *Dimensions of personality: Essays in honor of H. J. Eysenck.* Oxford, England: Pergamon Press.

Loo, R. (1979). Role of primary personality factors in the perception of traffic signs and driver violations and accidents. *Accident analysis and prevention, 11,* 125–127.

Mandler, G. (1975). *Mind and emotion.* New York: Wiley.

Mandler, G. (1979). Thought processes, consciousness, and stress. In Hamilton, V. & D. M. Warburton (Eds.), *Human stress and cognition* (pp. 179–201). London: Wiley.

McClelland, D. C. (1961). *The achieving society.* New York: D. Van Nostrand.

Minors, D. S., & Waterhouse, J. M. (1981). *Circadian rhythms and the human.* Bristol, England: Wright.

Monk, T. H., Knauth, P., Folkard, S., & Rutenfranz, J. (1978). Memory based performance measures in studies of shiftwork. *Ergonomics, 21,* 819–826.

Morris, L. W., & Liebert, R. M. (1970). Relationship of cognitive and emotional components of test anxiety to psychological arousal and academic performance. *Journal of Consulting and Clinical Psychology, 35,* 332–337.

Mulholland, T. M., Pellegrino, J. W., & Glaser, R. (1980). Components of geometric analogy solution. *Cognitive Psychology, 12,* 252–284.

Murray, H. A. (1938). *Explorations in personality.* New York: Oxford University Press.

Näätänen, R. (1972). Time uncertainty and occurrence uncertainty of the stimulus in a simple reaction time task. *Acta Psychologica, 36,* 492–503.

Navon, D., & Gopher, D. (1979). On the economy of the human processing system. *Psychological Review, 86,* 214–255.

Niemi, P., & Näätänen, R. (1981). Foreperiod and simple reaction time. *Psychological Bulletin, 89,* 133–162.

Norman, D. A., & Bobrow, D. G. (1975). On data-limited and resource-limited processes. *Cognitive Psychology, 7,* 44–64.

Norman, W. T. (1969). "To see oursels as ithers see us!" Relations among self-perceptions, peer perceptions, and expected peer-perceptions of personality attributes. *Multivariate Behavioral Research, 4,* 417–443.

Onken, J., & Revelle, W. (1983). *ANATEST: A program to generate geometric analogies varying elements and transformations.* Manuscript submitted for publication.

Pachella, R. G. (1974). The interpretation of reaction time in information-processing research. In B. Kantowitz (Ed.), *Human information processing: Tutorials in performance and cognition* (pp. 41–82). Hillsdale, NJ: Erlbaum.

Posner, M. I. (1978). *Chronometric explorations of mind: The third Paul M. Fitts Lectures.* Hillsdale, NJ: Erlbaum.

Posner, M. I., Snyder, C. R. R., & Davidson, B. J. (1980). Attention and the dection of signals. *Journal of Experimental Psychology: General, 109,* 160–174.

Poulton, E. C. (1976). Arousing environmental stresses can improve performance, whatever people say. *Aviation, Space and Environmental Medicine, 47,* 1193–1204.

Poulton, E. C. (1977). Continuous intense noise masks auditory feedback and inner speech. *Psychological Bulletin, 84,* 977–1001.

Poulton, E. C. (1978). A new look at the effect of noise: A rejoinder. *Psychological Bulletin, 85,* 1068–1079.

Poulton, E. C. (1979). Composite model for human performance in continuous noise. *Psychological Review, 86,* 361–375.

Poulton, E. C. (1981). Not so! Rejoinder to Hartley on masking by continuous noise. *Psychological Review, 80,* 90–92.

Rapoport, J. L., Jensvold, M., Elkins, R., Buchsbaum, M. S., Weingartner, H., Ludlow, C., Zahn, T. P., Berg, C. J., & Neims, A. H. (1981). Effects of caffeine in boys and adult males. *Journal of Nervous and Mental Disease, 169,* 726–732.

Reuman, D. A. (1982). Ipsative behavioral variability and the quality of thematic apperceptive measurement of the achievement motive. *Journal of Personality and Social Psychology, 43,* 1098–1110.

Revelle, W., Amaral, P., & Turriff, S. (1976). Introversion/extraversion, time stress, and caffeine: The effect on verbal performance. *Science, 192,* 149–150.

Revelle, W., Anderson, K. J., & Humphreys, M. S. (in press). Personality and performance: Tests of the arousal model. In G. Mangan & T. Paisey (Eds.), *Personality and temperament: An East-West typology.* Oxford, England: Pergamon Press.

Revelle, W., & Humphreys, M. S. (1983). *Personality, motivation, and performance.* Unpublished manuscript.

Revelle, W., Humphreys, M. S., Simon, L., & Gilliland, K. (1980). The interactive effect of personality, time of day, and caffeine: A test of the arousal model. *Journal of Experimental Psychology: General, 109,* 1–31.

Revelle, W., & Michaels, E. J. (1976). The theory of achievement motivation revisited: The implications of inertial tendencies. *Psychological Review, 83,* 394–404.

Rocklin, T. (1981). The effects of personality, absolute difficulty and relative difficulty on motivation and performance: A test of the dynamic theory of achievement motivation (Doctoral dissertation, Northwestern University, 1981). *Dissertation Abstracts International, 42*(5-B), 2138.

Rocklin, T., & Revelle, W. (1981). The measurement of extraversion: A comparison of the Eysenck Personality Inventory and the Eysenck Personality Questionnaire. *British Journal of Social Psychology, 20,* 279–284.

Sanders, A. F. (1983). Towards a model of stress and human performance. *Acta Psychologica, 53,* 61–69.

Sanders, A. F., & Reitsma, W. D. (1982). Lack of sleep and covert orienting of attention. *Acta Psychologica, 52,* 137–145.

Sanders, A. F., Wijnes, J. L. C., & van Arkel, A. E. (1982). An additive factor analysis of the effects of sleep loss on reaction processes. *Acta Psychologica, 51,* 41–59.

Sarason, I. G. (1975). Anxiety and self-preoccupation. In I. G. Sarason & C. D. Spielberger (Eds.), *Stress and anxiety* (Vol. 2, pp. 27–44). Washington, DC: Hemisphere.

Schalling, D. (1978). Psychopathy-related personality variables and the psychophysiology of socialization. In R. D. Hare & D. Schalling (Eds.), *Psychopathic behavior: Approaches to research* (pp. 85–106). New York: Wiley.

Seyle, H. (1976). *The stress of life* (Revised ed.). New York: McGraw-Hill.

Smith, B. D., Wilson, R. J., & Jones, B. E. (1983). Extraversion and multiple levels of caffeine-induced arousal: Effects on overhabituation and dishabituation. *Psychophysiology, 20,* 29–34.

Spence, J. T., & Spence, K. W. (1966). The motivational components of manifest anxiety: Drive and drive stimuli. In C. D. Spielberger (Ed.), *Anxiety and behavior* (pp. 291–323). New York: Academic Press.

Spence, K. W. (1956). *Behavior theory and conditioning.* New Haven, CT: Yale University Press.

Spence, K. W., Farber, I. E., & McFann, H. H. (1956). The relation of anxiety (drive) level to performance in competitional and non-competitional paired-associates learning. *Journal of Experimental Psychology, 52,* 296–305.

Thayer, R. E. (1967). Measurement of activation through self-report. *Psychological Reports, 20,* 663–678.

Thayer, R. E. (1978). Toward a psychological theory of multidimensional activation (arousal). *Motivation and Emotion, 2,* 1–34.

Thomas, E. A. C. (1983). Notes on effort and achievement-oriented behavior. *Psychological Review, 90,* 1–20.

Trumbo, D. A., & Gaillard, A. W. K. (1975). Drugs, time uncertainty, signal modality and reaction time. In P. M. A. Rabbit & S. Dornic (Eds.), *Attention and performance V* (pp. 441–454). London: Academic Press.

Vale, J. R., & Vale, C. A. (1969). Individual differences and general laws in psychology: A reconciliation. *American Psychologist, 24,* 1093–1108.

Weiner, B. (1966). Motivation and memory. *Psychological Monographs, 80*(18), 1–22.

Weiner, B. (1972). *Theories of motivation.* Chicago: Rand McNally.

Weiner, B. (1978). Achievement strivings. In H. London & J. E. Exner, Jr. (Eds.), *Dimensions of personality* (pp. 1–36). New York: Wiley.

Weiner, B., & Scheider, K. (1971). Drive versus cognitive theory: A reply to Boor and Harmon. *Journal of Personality and Social Psychology, 18,* 258–262.

Weiss, B., & Laties, U. G. (1962). Enhancement of human performance by caffeine and the amphetamines. *Pharmacological Review, 14,* 1–36.

Wenzel, D. G., & Rutledge, C. O. (1962). Effects of centrally-acting drugs on human motor and psychomotor performance. *Journal of Pharmaceutical Science, 51,* 631–644.

Wickens, D. D., Moody, J., & Dow, R. (1981). The nature and timing of the retrieval process and of interference effects. *Journal of Experimental Psychology: General, 110,* 1–20.

Wine, J. (1971). Test anxiety and direction of attention. *Psychological Bulletin, 76,* 92–104.

Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimuli to rapidity of habit-information. *Journal of Comparative Neurology and Psychology, 18,* 459–482.

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